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PHYSIOGRAPHIC FEATURES OF SOUTHEASTERN OHIO

WILBER STOUT AND G. F. LAMB

INTRODUCTION

In a general way the physiographic features of southeastern Ohio, that is, the area south and east of the glacial boundary, appear complex due to the series of events that have taken place in the region. The results, largely the work of water, now appear as peneplains, straths, cuestas, stream changes, terraces, fills, and other features of less importance. Aside from water, other agencies and modifying influences are, direct and indirect action of glaciers, crustal movements, dip of strata, kind of rock on outcrop, affectibility of strata by weathering, ease of suspension, etc. The work of sculpturing the land surface began with uplift at the close of Permian time and has continued to the present. The quantity of work accomplished at different times has varied due to the agencies at work, to the intensity of the forces and to the time they were active. The area contains many features of interest.

PHYSIOGRAPHIC FEATURES AND ORDER OF EVENTS

The prominent physiographic factors in southeastern Ohio may be listed in the following order, beginning with the oldest.

(1) Monadnock hills and ridges, representing possible remnants of the original surface.
(2) Harrisburg peneplain, the oldest well defined erosion surface.
A. Uplift and rejuvenation.
(3) Lexington peneplain, best developed to the west.
B. Uplift and rejuvenation.
(4) Parker strath with Teays, Pittsburgh and Dover drainage systems developed.

C. Flooding and filling of valleys through damming by early drift sheet, possibly Jerseyan.
D. Uplift and rejuvenation.

(5) Deep stage drainage with Cincinnati, Newark and Pomeroy drainage developed.
E. Cutting of valleys much below that of the older system.
F. Advance of Illinoian ice with consequent changes.

(6) Post-Illinoian drainage with the development of the New Martinsville, Post-Illinoian Muskingum and Post-Illinoian Hocking rivers.
G. Cutting of cols and formation of new valleys.
H. Advance of Wisconsin ice with again a shift of drainage.

(7) Present drainage system of the Ohio, Tuscarawas, Muskingum, Hocking, and Scioto Rivers.
I. Removal of outwash, formation of terraces, new channels, etc.

Monadnock Hills and Ridges

Throughout southeastern Ohio many knobs and ridges stand out as monadnocks, which are elevations projecting above the surface of a peneplain. Many of these are definite and distinct. The number and distribution of these suggest that they are the remnants of a once higher level or of the original surface. In either case it was destroyed by succeeding cycles of uplift and erosion. Near the close of the Paleozoic era crustal movements resulted in the building of the Appalachian Mountains and also in the uplifting, to where erosive agencies became active, of much territory (such as the Allegheny Plateau) bordering these highlands. During the Mezozoic era that followed, these land areas were severely attacked by erosion and eventually brought to a base leveled condition. Again other cycles of uplift and erosion further reduced the highland areas, and produced the plateau surfaces as we now know them.

The monadnock hills and ridges are well distributed over southeastern Ohio, yet their crests lack uniformity, indicating that they are only mere remnants of a higher surface. In Columbiana, Jefferson, Belmont, and Monroe counties these features stand out from a peneplain with an elevation varying from 1,260 to 1,280 feet. The common average is considered at 1,270 feet.

In Columbiana County the outstanding hill, the highest in southeastern Ohio, is Round Knob located in Section 22, Madison Township, and having an elevation of 1,447 feet. It is capped with the Morgantown sandstone, a bed prominently developed to the southwest in Jefferson County. In Wayne Township west of Madison some of the high knobs which rise from 1,350 to 1,385 feet also carry the Morgantown sandstone as the cap rock. These deposits are thus outliers from the main field and have been cut off by erosion. In all, in Hanover, West, Center, Wayne, and Madison townships eleven knobs or ridges have elevations above 1,365 feet and four of them above 1,410 feet.

To the southwest of this in Jefferson County the entire area has been reduced close to the peneplain surface as the highest knob rises only to 1,388 feet and as only four are above 1,345 feet. These knobs, however, rise much higher geologically as some of them extend well up into the Dunkard series of the Permian. The upper surface of Carroll County is also well reduced as the ridge crests remain rather constantly at 1,260 feet. The only noteworthy exceptions are two knobs in Fox Township, one rising to 1,350 feet and the other to 1,370 feet. The ridges all end geologically in the Conemaugh series.

The monadnocks in Belmont County show some increase in elevation, are more numerous, and are more widely distributed. The highest knob, 1,400 feet, is in Goshen Township and the next highest, Galloway knob, 1,397 feet, in Smith Township. In all ten knobs or ridges rise from 1,350 to 1,400 feet. The rocks capping these are strata well up in the Dunkard series, the highest being shales and sandstones above the Ninevah coal.

These special features, high knobs and ridges, are most outstanding in Monroe County where six hills rise above 1,400 feet and twenty or more above 1,360 feet. Mainly the cap rocks are beds in the Greene formation of the Dunkard series, and are thus the highest strata in the consolidated rocks of Ohio. In eastern Harrison County a few knobs in Archer, German, Rumley, Lee, and Cadiz townships rise to 1,350 feet or more, the highest being approximately 1,370 feet. Most of these are capped with rocks in the basal portion of the Monongahela formation. In the western part of the area the ridge crests remain close to the 1,260–1,280 foot peneplain level.

To the west of this highland area or in Tuscarawas, Coshocton, Guernsey, Muskingum, Washington, Noble, Morgan, Athens, Hocking, Jackson, Pike, Meigs, Gallia, Lawrence and Scioto counties, the destructive agencies have been severe, the results being a basin in which few ridges rise above the 1,260–1,280 foot level and in which in large areas the general ridge crests are much below this contour. The lower plain is that of the Lexington peneplain, discussed later.

The high plain with monadnock knobs and ridges in southern Columbiana, eastern Carroll, Jefferson, eastern Harrison, Belmont, and Monroe counties constitutes the highland area of southeastern Ohio. The number and wide distribution of these elevations show that they are remnants of much additional strata that escaped complete destruction. The thickness or quantity removed is not known but was certainly more than one hundred feet, probably much more. If the Permian rocks were laid down in this area to the full thickness shown in West Virginia, then several hundred feet was lost through base leveling. The monadnocks thus appear as remnants of a higher surface that through severe erosion has lost distinctive features.

Harrisburg Peneplain

General features

A careful survey of the highland area in southeastern Ohio in Columbiana, eastern Carroll, Jefferson, eastern Harrison, Belmont, and Monroe counties shows that most of the higher ridges reach a rather uniform elevation of about 1,260–1,280 feet. These flat surfaces on the ridges mark the position of the Harrisburg peneplain. Generally these ridges are prominently broad and flat and are the sites for towns, villages, farm homes and highways. The culture in this area is thus, in the main, on the ridges and not in the valleys or it is in direct contrast to what it is in the area to the west. The highland area of eastern Ohio with its well-developed Harrisburg peneplain is distinctive in many ways, especially physiographically.

Flushing escarpment

The western boundary of this highland area is an outstanding physiographic feature of the region and is marked by the escarpment and the change in the pattern of the contours where the Harrisburg peneplain breaks down to the lower

Lexington level. This distinct modification is called by the writers the Flushing escarpment from the name of the village in Belmont County where the change is so conspicuously developed. Diagram 1, taken from the Flushing topographic sheet, shows this change of contour pattern very well.

The pattern east of the Flushing escarpment in this respect lacks the deep indentations of that to the west. Thus the surface east of the escarpment in contrast to that to the west has wider ridges, less direct relief, fewer small streams, and in general more uniformity. The boundary is on the old water

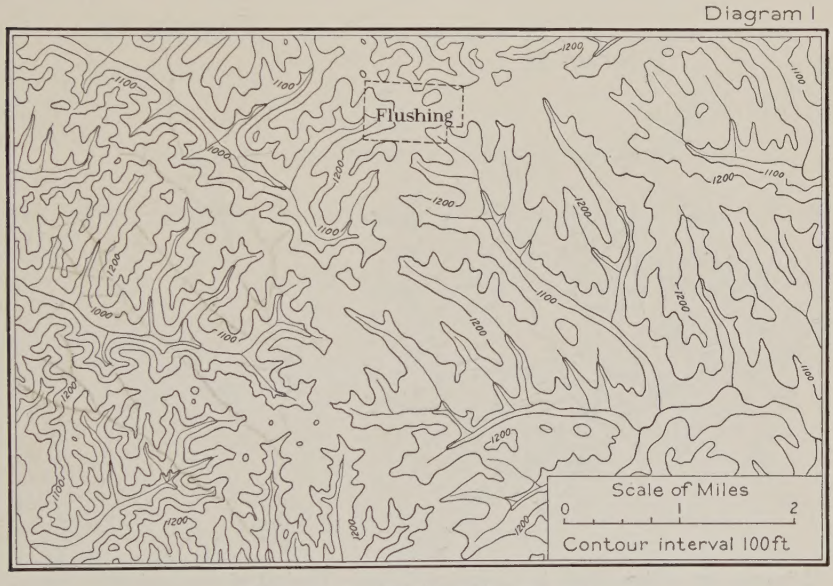


Diagram 1. Flushing Escarpment.

divide separating major streams of Teays time. This escarpment is readily traced by the change in elevation of the ridge summits and by the difference of contour pattern.

The Flushing escarpment passes from the drift border near Kensington, Columbiana County, southward through Morristown, Mechanicstown, Harlem Springs, and Kilgore, Carroll County, through Germano, Folk, and Cadiz, Harrison County, through Flushing, Morristown, Bethesda, Speidel, Barnesville, and Boston, Belmont County, and through Monroefield, Lewisville, Woodsfield, Mt. Carrick, Round Bottom, Morton and Goodwin to the Ohio River about two miles above Hannibal,

Monroe County. Along most of this course the Flushing escarpment is well and definitely defined but locally it is evidently modified, suggesting local shifting through stream advancement.

CONTRAST OF HARRISBURG AND LEXINGTON AREAS

The Harrisburg and Lexington peneplain areas show differences worthy of comment. The proportion of land above the 1,260 foot contour is much greater in the Harrisburg area than it is in the Lexington where the forces of erosion were

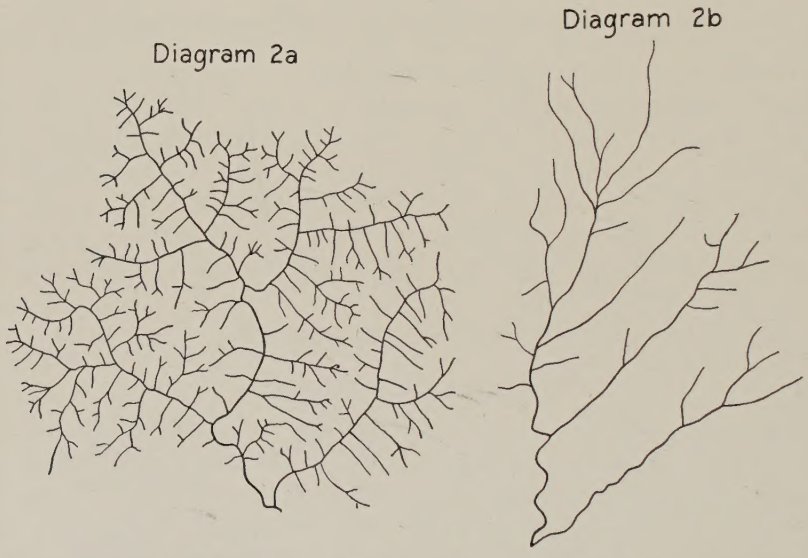


Diagram 2a. Pine Creek in Lawrence County Typical of the Lexington Area.
Diagram 2b. Baker Fork near Woodsfield in Monroe County Typical of the Harrisburg Area.

more in evidence in reducing the uplands and in dissecting the plains. The ridge flats of the former generally carry a rather definite type of soil, evidently formed in part from materials left by the degrading forces with subsequent weathering and leaching. The Harrisburg and Lexington areas are contrasted also in the patterns of the streams and in the gradients of the floors. In the Lexington area the streams have developed mature dendritic patterns whereas in the Harrisburg they are far less sculptured. This is best shown by diagrams 2a and 2b.

This dissimilarity in pattern is due to the difference of intrenchment developed by the streams from their inception to the close of Teays time. This long erosion cycle thus gave

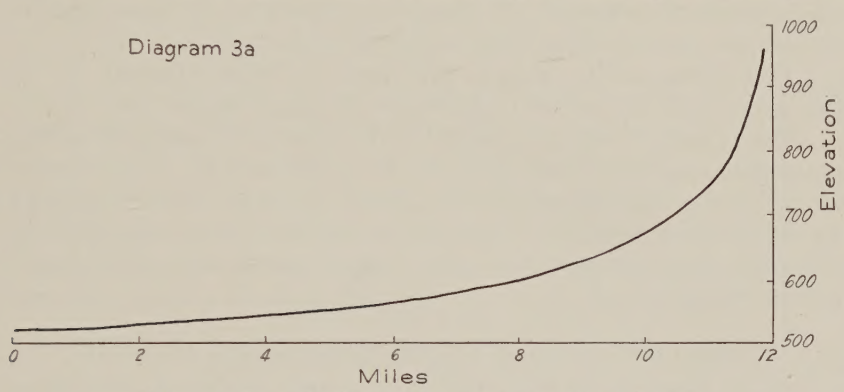


Diagram 3a. Gradient of Ice Creek, Lawrence County.

rise to the surface sculpturing of the uplands. West of the Flushing escarpment or in the Lexington area the valleys were more deeply intrenched and more mature than were those east

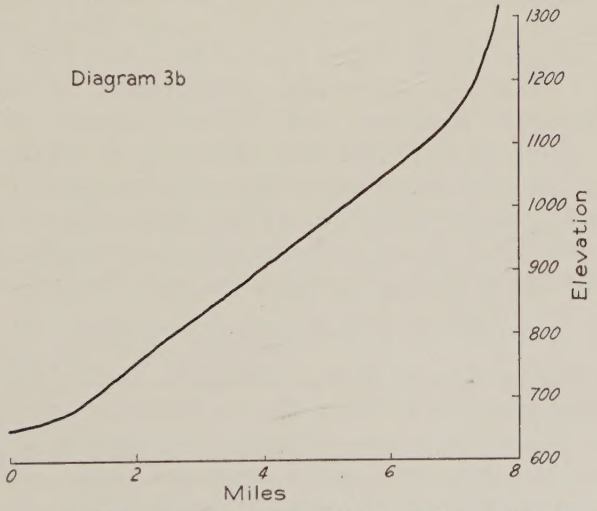


Diagram 3b. Gradient of Pipe Creek, Belmont County.

of this break or in the Harrisburg area. The cause for this is not clear, but appears to be that the area west of the escarpment was in the lower part of a great drainage basin whereas that east of this physiographic line was at the headwaters of streams that

had far to flow before reaching the sea. Further, the nature of the rock was, to some extent, a modifying factor. The soft shale of the Conemaugh series gave way more readily than the fresh-water limestones of the Monongahela or the massive sandstones of the Allegheny and Pottsville.

The difference in stream gradients is quite marked in the two areas. This feature is shown in diagrams 3a and 3b.

The streams in the Lexington area have low gradients along their lower courses with little or no intrenching. The cutting is mainly at the headwaters. Such streams show maturity in the cycle of erosion. The streams in the Harrisburg area, in contrast, have rather high and uniform gradients throughout. Intrenchment is still going on throughout much of their courses.

HARRISBURG LEVEL WEST OF FLUSHING ESCARPMENT

Throughout that part of Ohio south of the drift border and west of the Flushing escarpment the Harrisburg peneplain level is identified by the higher ridge crests throughout much of the area. The common elevation, however, descends considerably below that in the highland area east of the Flushing escarpment. Throughout much of Carroll, Tuscarawas, Holmes, western Harrison, southwestern Ross, western Pike, and eastern Adams counties many ridges reach the 1,260 foot level. In much of Coshocton, Guernsey, Muskingum, Noble, Washington, Morgan, Hocking, and Athens counties they range between 1,100 and 1,260 feet, whereas in Meigs, Gallia, Lawrence, and Scioto counties they seldom exceed 1,100 feet and many are much below this. These ridge crests thus appear to mark the floor of some ancient drainage basin that gave rise to the base leveling and drained southwest into Kentucky.

HIGHLAND AREAS WITHIN THE DRIFT

Other highland areas within the State, but within the field of drift, comparable in elevation (1,260–1,280 feet) to that in eastern Ohio, are found around Loudonville in Morrow, Richland, Ashland, and Knox counties, near Chardon in Geauga, near Zanesfield in Logan and Champaign, and around Chillicothe in Ross. The first mentioned area includes northeastern Morrow, southern Richland, northern Knox, and southwestern Ashland counties. This is really the highland area of Ohio as the general elevation of the ridge crests is higher here than elsewhere in the State. The region is considerably

smoothed by drift. The area around Chardon is relatively small and belongs at the crest of the wall of the Portage escarpment that stretches eastward from Cleveland to Albany, New York. The area in western Ohio in Logan and Champaign counties is capped by Campbell Hill, 1,550 feet, the highest point in the State. It is drift covered. The Zanesfield area includes eastern Logan and, with less definition, eastern Champaign County. In the Chillicothe area the highest ridges are east of the Scioto River in the vicinity of Mount Logan and south of Paint Creek near that of Copperas Mountain. These widely scattered remnants thus show that the 1,260–1,280 foot level was defined across the State.

UPLIFT AND REJUVENATION

Harrisburg peneplanation was brought to a close by uplift and rejuvenation, regional in extent and in influence. This movement was certainly not violent but appears to have been slow and orderly. In Columbiana County the total rise was some 140 feet and in Vinton County not far from 100 feet. After this event another long period of crustal stability gave rise to the second stage of base leveling resulting in the Lexington peneplain.

Lexington Peneplain

GENERAL FEATURES

The Lexington peneplain, also known as the Worthington, received its name from the regularity of the ridge crests in the Bluegrass region near Lexington, Kentucky. In the unglaciated part of Ohio this erosion level is best represented in eastern Scioto, Lawrence, Gallia, Meigs, Jackson, and Vinton counties. During the upwarping the streams with renewed activities soon cut deep valleys in the older surface and during the long period of crustal quiescence that followed they gradually developed wide gradation plains along their courses and also reduced the water divides between many basins to much lower levels.

West of the Flushing escarpment the Lexington level is well defined but east of this it is commonly only a strath stage and in some areas without apparent definition. It appears as shoulders, from 1,100 to 1,160 feet, along Little Beaver and West Fork in Columbiana County, along Short Creek in Jefferson, along Wheeling, McMahon, and Captina creeks in

Belmont, and along Sunfish Creek in Monroe. West of the Flushing escarpment the common crest level along the divides is 930 to 990 feet. This surface is best defined in eastern Scioto, Lawrence, Gallia, Meigs, Jackson, and Vinton counties and is marked to a less extent in eastern Hocking, western Athens, western Morgan, Perry, and central Muskingum counties. The general effect is that of a low flat basin the trough of which slopes in a general way southwestward into Kentucky. Lexington peneplanation is accredited to late Tertiary time.

Certain features warrant the assumption that the high-level surface east of the Flushing escarpment, called Harrisburg, is really the same in age and in origin as the one from 250 to 300 feet lower to the west of the divide, known as Lexington. The two, however, differ not only in elevation but in intensity of sculpturing and in maturity of drainage. Such distinctions may be due to many contributing elements operating under somewhat different conditions. The area east of the Flushing escarpment was drained by a stream flowing eastward to the sea, whereas that west of the divide was drained by one flowing westward to the gulf. These master streams differed in the length of the courses, in the gradient of the floors, in the physiographic provinces traversed, in the nature of the rocks eroded, in the dip of the strata and in other factors of less importance. Such causes may be sufficient to account for the distinctive features of the two areas, truly correlative in age.

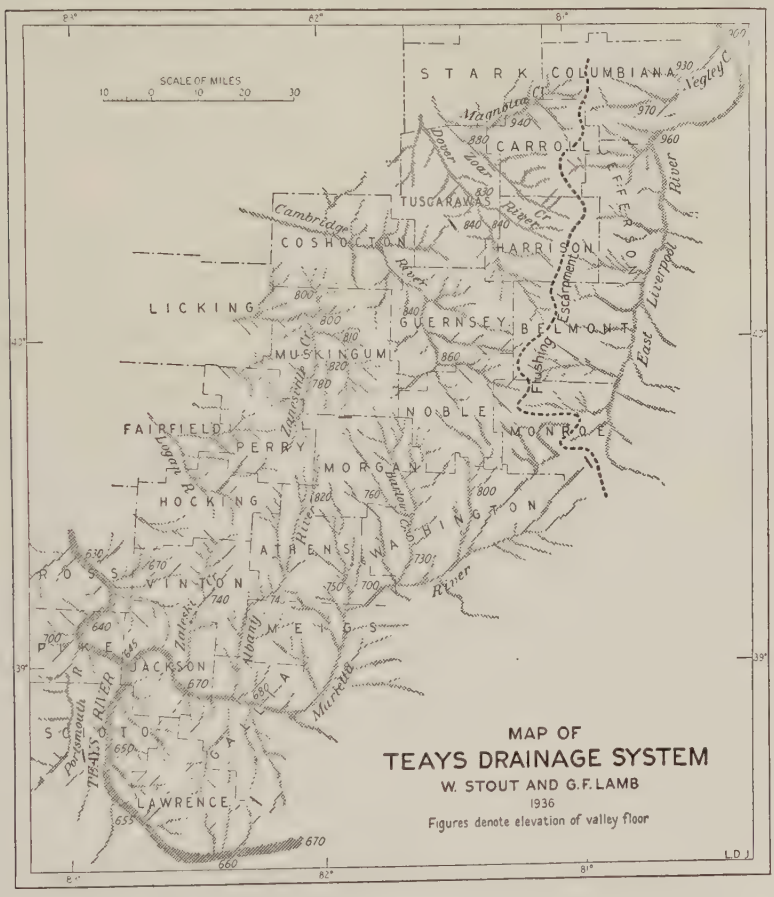
UPLIFT AND REJUVENATION

Again regional uplift prevailed with consequent rejuvenation and with the initiation of another cycle of erosion. In general the floors of the new streams thus formed in the unglaciated part of Ohio were from 150 to 190 feet below the Lexington or 260 to 340 feet below the older Harrisburg peneplain. At the other extreme of the unglaciated area, Scioto County, the floors of the major streams of this cycle of erosion now stand from 640 to 740 feet above tide. This causes them to fall from 190 to 250 feet below the Lexington level here the main peneplain for reference. The latter condition, or interval, is not far different in the other counties west of the Flushing escarpment.

Parker Strath—Teays Drainage Stage

GENERAL STATEMENT

The third well-defined modification of the surface through the work of erosive agencies is the Parker strath which is the name applied collectively to the remnants of old valleys formed



by stream action just prior to the first ice invasion or in late Tertiary time. This general stage of erosion is commonly referred to as Teays because the master stream, as now known, of that period was the Teays which was of wide lateral extent, had important modifying influences, and left many interesting features for future study. The Parker strath may be defined

as an immature peneplain or erosion level, the work of streams during Teays time. (See map of Teays Drainage System.)

WORK DONE DURING TEAYS TIME

This new cycle of erosion was inaugurated by a slow uplifting of the land that brought to a close the long period of quiescence which resulted in the formation of the Lexington peneplain. As a consequence of this upward movement of the surface by internal forces the streams were rejuvenated and began carving valleys in the recently elevated plain. The Parker cycle was short compared to the more remote Lexington and Harrisburg but yet it was of sufficient duration for a large amount of work to be done. The streams of Teays time maturely dissected much of the older gradation surfaces and lowered many of the water divides. In general they cut rather broad valleys with moderate slopes from 150 to 250 feet below the mean level of the Lexington peneplain. The uplifting appears to have been gradual or at least without prolonged pauses as rock cut terraces are not conspicuous at any position on the valley walls. The Parker cycle was brought to a close by the advance of an early ice sheet, probably Jerseyan which caused general modification and rearrangement of the drainage systems of the entire region.

EARLY RECOGNITION OF OLD STREAMS

Drainage modifications are so conspicuous in the unglaciated part of the State, especially the southern portion, that they were noted by most of the geologists that worked in this field. Prominent deserted valleys, sudden changes in soils, peculiar types of clays, beds of gravel and sand, buried wood, rounded stones, etc., were evidences that attracted the attention and led to speculation if not to definite records. The history of drainage changes goes back to the recorded observations of that great scientist and master mind, Dr. S. P. Hildreth, of Marietta. In the First Annual Report of the Geological Survey of Ohio, dated January 17, 1838, he states under the title "Fossil fresh water shells,—Bed of ancient Lake":[1]

"On Mr. Lawton's farm, in Barlow township, Washington County, in the midst of the marl region, is a locality of fossil fresh water shells, of the genus *Unio*. They are imbedded in coarse sand or gravel, cemented by ferruginous matter. The

[1]First Annual Report, Geological Survey of Ohio, 1838, p. 50.

specimens are casts, replaced by an argillaceous oxide of iron. The spot in which they are found, has once evidently been the bed of an ancient lake or pond. It is now a beautiful valley of a mile or more in width, by four miles in length, surrounded by low hills. On the south side, a small branch drains the superfluous water into the Little Hocking. In digging wells for domestic use, in this tract, beds of sand, gravel and plastic clay, are passed to the depth of 30 feet, containing imbedded branches of trees, leaves and fragments of wood, of recent and living species. Similar valleys and levels are found in the uplands of the western part of the county, lying between the head waters of the creeks, and are a kind of table land. From the frequency of these flat lands between the head waters of the Little Hocking and the south branch of Wolf creek, it is quite possible that, at some remote period, the waters of Wolf creek were discharged into the Ohio river instead of the Muskingum. This opinion is strengthened from the fact, that the head branches of the south fork now rise within two miles of the Ohio, and run northerly, parallel with and opposite to, the course of the Muskingum for 12 miles, and joins that river, 20 miles from its mouth. The remains of its ancient beds would form pools and ponds of standing water, furnishing fit residences for the fresh water shells, whose fossil remains are now found there. Great changes have, evidently, been made in the direction of all our water courses, before they found their present levels."

The old stream here described, was of Teays time, rose in the upper reaches of what is now the Meigs Creek basin, flowed southward past Waterford, Watertown and Barlow to the old Marietta River at the village of Little Hocking, on the Ohio.

The geologists contributing to the survey of Ohio in 1869 and 1870 made a few comments but no lengthy discussions on drainage changes. Read, however, in 1878, describes with considerable detail the ancient river systems in Knox County and Orton, in the same year, traces the old streams connecting the valleys of the two Miamis in Warren County. The drainage of western Pennsylvania became of interest between 1890 and 1900 when Foshey, Hice, Chamberlin, and Leverett began to trace the old water ways with much care. Tight in 1897 began serious work on the old drainage systems in central Ohio and in 1903 wrote his masterpiece on the Teays in southern Ohio and adjacent parts of West Virginia and Kentucky. Other

workers of this time were Bownocker, Todd, Fowke, Clark, and Davis. Since 1900 considerable work has been done on local modifications or on special phases of ancient drainage by Campbell, Lamb, Scheffel, Hubbard, Hyde, Conrey, Stout, Coffey, Lamborn, Ver Steeg, White, Scranton, Sharp, Cole, Happ, and others.

TEAYS RIVER

The master stream, the Teays River, rose far out in the Piedmont of North Carolina and Virginia, flowed northwestward to Charleston, West Virginia, thence westward along the route now followed by the Chesapeake and Ohio Railway past St. Albans, Milton, and Barboursville to the present valley of the Ohio River at Huntington. From this place its course was much the same as that of the present stream, the Ohio River, to Wheelersburg, Ohio, where the two courses change radically. From Huntington to Wheelersburg, however, the old Teays floor is well recognized by wide flats south of Ashland, Kentucky, and by prominent terraces between Franklin Furnace and Wheelersburg on the Ohio side. From Wheelersburg the present stream flows westward towards Portsmouth and Cincinnati, whereas the preglacial Teays River continued northward past Minford, Stockdale, Glade, Beaver, Givens, Waverly, Richmondale, and Vigo to Chillicothe, beyond which the old valley is buried with a thick mantle of glacial drift. From Chillicothe, however, the course is traced with some certainty to near Circleville where, from work of Ver Steeg, the stream turned and then flowed northwestward past the St. Marys Reservoir, finally ending in the Gulf then extended far northward.

The rock floor of the old Teays River as determined has an elevation of about 670 feet at Scary, West Virginia, 660 feet at Huntington, 650 feet at Russell, Kentucky, 650 feet on Dogwood Ridge near Wheelersburg, Ohio, 640 feet at Glade, 640 feet at Waverly, and 630 at Chillicothe, beyond which the floor is deeply buried by drift. For this distance the gradient of the old floor is low, only about 4 inches per mile. The stream was thus quite mature and had reached its maximum depth of cutting.

The width of the valley proper varies from 1 to 2 miles but averages not far from 1.45 miles. In general from Huntington, West Virginia, to Chillicothe, Ohio, the width is

rather uniform, widening somewhat down stream through the influence of various tributaries, some of fair size. Throughout this part of the course the depth of cutting or the relief at that period was about 300 feet. This is the difference between the floor level of the Teays River at 630 to 660 feet and that of the ridge summits of the Lexington peneplain at 930 to 960 feet. Such differences, however, decreases as the tributary streams, as the Marietta, Portsmouth, Albany, Zaleski, etc., are followed headward.

In general the hills bordering the Teays River and its larger tributaries are low and well rounded, the resultant of prolonged, rather mature erosion. Their height and shape, however, are influenced by the nature of the rocks composing them. Where shales predominate the relief is much more gentle than where sandstones are the dominating strata. Within the entire Teays basin in Ohio south of the drift border the streams have maturely dissected the uplands. The pattern is decidedly dendritic, even to the small runs and rills at the headwaters. The floor gradients also show an advanced stage in the erosion cycle.

The old Teays Valley is well preserved and open for study in many places along its course. In West Virginia the outstanding examples are along the route of the Chesapeake and Ohio Railway from St. Albans to Barboursville and the wide flats southeast of Huntington. In Kentucky the floor with its characteristic silts is well defined south of Ashland and Russel. In Ohio the course of the Teays River is clearly marked all the way from Wheelersburg in Scioto County to Chillicothe in Ross. From the Sun Hill near Wheelersburg one may gaze eastward across the Teays Valley, northward down the course of this ancient stream, southward into the valley of the Ohio, with the Deep Stage buried by about 100 feet of silt, sand, and gravel, and westward to the col between the Teays and Portsmouth rivers. The village of Minford in northern Harrison Township, Scioto County, is the type locality for Minford silt, here so well exposed in the cut of the Chesapeake and Ohio Railway. The old valley with only minor modifications is well defined northward from Minford past Stockdale to Glade where it was joined by the Marietta River. From Glade westward past Beaver and Givens to the Scioto River both the Teays and the present drainage forms interesting studies. Northeast of Waverly the Teays and present drainage parallels

one another, the streams flowing in the opposite directions. From Richmondale northward to Vigo, to Londonderry, and on to Chillicothe the old valley is much modified by deposits from the Illinoian and Wisconsin drift.

MINFORD SILT

Throughout southern Ohio and in adjacent parts of West Virginia and Kentucky, the preglacial drainage lines are all much choked with highly laminated silt, fine sand, and, very locally, coarse rubble. Such materials are found not only along the main waterways of the Teays drainage systems, but also far up the smaller tributaries. The deposits on the old floors are best preserved in the parts of these valleys that do now form divides between present streams and in the parts that were abandoned through piracy, meanders, and other adjustments.

The outstanding deposits in these old valleys are the plastic, highly laminated silts which are well distributed throughout the entire basin, being present locally on the small tributaries as well as on the main stream. The thickness of such deposits varies from 10 to possibly more than 80 feet, but usually the measurements range from 20 to 40 feet.

These silts, called Minford from exposures near that village, are always highly laminated, the laminae being closely and regularly spaced. The material is extremely fine in grain, has a sticky plasticity with little dry strength and has a smooth feel, either wet or dry. The unoxidized color is dark bluish gray and the weathered is brownish gray to drab shades.

The following analyses are representative:

Analyst—Downs Schaaf.

	No. 1	*No. 2*	*No. 3*	*No. 4*
Silica, SiO_2	55.91	50.02	53.40	57.35
Alumina, Al_2O_3	17.30	23.10	28.08	24.16
Ferric oxide, Fe_2O_3	8.58	7.08	4.50	5.25
Ferrous oxide, FeO	1.33	1.16	.....	.....
Titanic oxide, TiO_2	1.00	.74	.75	.80
Phosphorous pentoxide, P_2O5	.18	.75	.10	.11
Manganous oxide, MnO	.06	.05	.02	.03
Calcium oxide, CaO	.90	.86	.66	.48
Magnesium oxide, MgO	2.41	2.80	1.94	1.46
Potassium oxide, K_2O	3.25	4.40	4.40	4.84
Sodium oxide, Na_2O	.45	3.43	trace	.10
Sulphur, S	.04	.015	.....	.....

Water, hydroscopic, H_2O-	2.52	2.77	5.13	5.10
Water combined, H_2O+	5.27	3.23		
Carbon, organic, C	.25	.05	.50	.10
Carbon dioxide, CO_2	.72	.04	.30	none

No. 1. Sample taken by R. E. Lamborn, 1929, at cut at Minford, south central Section 33, Madison Township, Scioto County.

No. 2. Sample taken by W. Stout and Downs Schaaf, 1928. Sample taken mainly from upper layer at same locality.

No. 3. Sample taken by W. Stout and Downs Schaaf, 1928, east central Section 25, Union Township, Pike County.

No. 4. Sample taken by W. Stout and Downs Schaaf, 1928, northeast quarter Section 18, Seal Township, Pike County.

The Minford silts are characterized by fineness and uniformity of grain, by high plasticity, by closely spaced laminations, by high content of sericitic mica and by a consistency of character throughout a wide area. They were deposited in rather deep and comparatively quiet waters which were ponded to lake-like conditions throughout the valleys had slight motion and stood well towards the rims of the basins. The high content of sericitic mica indicates that the Minford silts were derived largely from the schists of the Piedmont and therefore the streams headed well out on this old highland. Through obliteration of the lower courses of the Teays streams by glacial action and through flooding of the remaining parts of the courses new drainage lines were established simply by the ponded waters pouring over low divides and cols, thus seeking new ways for outlet to the sea. The new streams, known as Deep Stage drainage, flowed undisturbed until they cut youthful valleys much below the former, or Teays, drainage level.

TRIBUTARIES OF TEAYS

In southern Ohio the master stream of the Teays system was joined by a number of tributaries a few of which were of fair size. The largest of these was the Marietta River, a stream that gathered its headwaters near Marietta, flowed southwestward past Parkersburg, West Virginia, Little Hocking, Coolville, Tuppers Plains and Chester, Ohio, to Hartford, West Virginia, thence across Mason County in that state to Cheshire, Ohio, thence southwestward along the present valley of the Ohio to near Gallipolis where its course was deflected northwestward past Rodney, Rio Grande, Centerville, Clay, Camba,

Keystone, Jackson and Cove to Glade, there joining the Teays River. Some of the larger tributaries of the Marietta were the Albany River, Zaleski Creek, and Barlow Creek.

PORTSMOUTH RIVER

The Portsmouth River rose near Manchester in Adams County, flowed eastward along what is now the valley of the Ohio past Rome and Buena Vista to Portsmouth, thence northward past Lucasville, Wakefield and Piketon to near Waverly where it united with the Teays. Remnants of the old Portsmouth Valley, not greatly disturbed, are found east of Lucasville, east of Clifford, at the mouth of Camp Creek, east of Wakefield and east of Piketon. In fact, from Portsmouth to Piketon the present Scioto occupies no large part of the old Portsmouth Valley.

LOGAN RIVER

The Logan River, a stream of Teays time, headed near the Athens-Hocking County line on the present Hocking River, flowed northward past Haydenville, Logan and Lancaster to either a large tributary or to the main stream of the Teays River. Old floor levels with Minford silts are present in many places near Union Furnace, Logan, Haydenville, Webb Summit and Greendale. The northern portion of the valley is filled with outwash and glacial drift.

PUTNAM CREEK

In Muskingum, eastern Licking and northeastern Perry counties remnants of drainage of Teays time are quite distinct in local areas. This stream may be called Putnam Creek as the old floor is so well preserved west of this place. It gathered its headwaters south of Crooksville in northeastern Perry County, flowed northward past Roseville, South Zanesville and Putnam to Shannon, thence westward to Newark where the old floor is lost in drift. A tributary of this stream rose near the Morgan-Muskingum County line, flowed northward past Philo to Sonora, thence westward joining Putnam Creek a few miles north of Zanesville. Remnants of old floors are well defined near Chandlersville, Sonora, Gilbert and Shannon. Typical Minford Silts are present near Roseville, Moxahala, South Zanesville, and Putnam, indicating that this stream was a direct tributary to the Teays. The elevation of the floor of Putnam Creek is

not far from 780 feet at Moxahala, 770 feet at Putnam, and 760 feet at Shannon, and that of the tributary 780 feet at Carlwick and 770 feet near Sonora. Along the course of this stream the bordering hills are commonly low and well rounded, a maturity indicative of that of the Teays.

CAMBRIDGE RIVER

The headwaters of the Cambridge River, the old stream of Teays time, was the same as that now drained by Wills Creek. It rose just west of the Flushing escarpment and had maturely dissected the area. Its course was northwestward past Cambridge, Kimbolton, Birds Run and Plainfield to West Lafayette where it entered the great valley now occupied by the Tuscarawas. From West Lafayette the course of the Cambridge River is not so definite as there is little evidence in support of either route. The main trend would project it past Coshocton and Warsaw to Millwood beyond which the bed is deeply buried by drift. Such a course would place a col on the Muskingum River near Adams Mills and another on the Tuscarawas near Gnadenhutten. Remnants of old floors are seen near Cambridge at an elevation of 840 feet, near Plainfield at 800 feet, and near Coshocton at 780 feet.

DOVER RIVER

One of the important early streams of southeastern Ohio was what may be called the Dover River which with tributaries drained parts of Belmont, Guernsey, Harrison, Tuscarawas, Holmes, Carroll, Columbiana, and Stark counties. These streams gathered their waters north and west of the Flushing escarpment in an area the general topography of which is much like that in the Teays basin. The Dover River headed far south, less than twenty miles from the Ohio River, in northwestern Belmont, northeastern Guernsey and western Harrison counties, in an area now drained by Stillwater Creek. The ancient stream flowed northward past Freeport, Uhrichsville, Dover and Beach City to Navarre where a thick mantle of drift leads to obscurity. The Dover River was joined by eastern tributaries, one in the valley now occupied by Conotton Creek and another in that of Sugar Creek. Owing to deep filling of drift and outwash and to obliteration by the succeeding stages of drainage, remnants of the floor of the Dover River are not conspicuous. The few observations such as at Newport

and Magnolia indicate that the main streams stood at elevations between 860 and 900 feet. The evidence is in support of the Dover River flowing on northward into the Lake Erie basin.

PITTSBURGH RIVER

The course of the Pittsburgh River has been carefully traced by Foshay, Hice, Leverett, Chamberlin, Campbell, Lamb and others throughout its extent south of the drift border. The main stream gathered its headwaters in the basins now occupied by the Allegheny and Monongahela rivers and flowed northwestward from Pittsburgh to Beaver, thence northward past Beaver Falls and New Castle to Hubbard, thence westward to Youngstown, and thence northward where it soon becomes lost under a deep mantle of drift. Evidence now available indicates that it flowed on northward through the Grand River basin to Lake Erie.

STEUBENVILLE RIVER

In Ohio, aside from the lower course of the main stream, the chief interest is a tributary that rose just east of the Flushing escarpment near Hannibal in Monroe County, flowed northeastward past Clarington, Bellaire, Steubenville and East Liverpool to Beaver, Pennsylvania, where it united with the main stream of the Pittsburgh River. This tributary, here called the Steubenville River for the sake of definition, drained parts of Monroe, Belmont, Harrison, Carroll and Columbiana counties and all of Jefferson. Another small tributary, distinctively named Negley Creek, drained most of Columbiana County. The Steubenville River and Negley Creek thus received the waters from the highland area of southeastern Ohio, the western border of which is the Flushing escarpment.

Along the upper course of the Steubenville River little evidence remains of old floors as the main stream and its tributaries had dissected little below the level of the Lexington peneplain, here only a strath stage. Further, through succeeding stages of cutting the streams simply dug themselves deeper in the same courses, thus obliterating the early prints, that of Teays time. Some shoulders, terraces and floors assigned to this stage appear at 1005 feet at Wellsburg, 990 feet at Costonia, 985 feet at New Cumberland, and 960 feet near Wellsville and East Liverpool. Along Negley Creek the evidence is more conclusive as the old floor is distinct in many

places. Near West Point the floor of the broad upland valley has an elevation not far from 970 feet and at Negley close to 930 feet. The Pittsburgh River thus draining the highland area of southeastern Ohio was a system separate and distinct from the Teays. The former evidently discharged its waters eastward to the Atlantic Ocean and the latter carried its load westward through the interior basin to the Gulf of Mexico.

EFFECTS OF AN EARLY GLACIER

The evidence supporting an early drift sheet, possibly Jerseyan, that touched Ohio, is more from effects on drainage than from direct deposits left from such an ice invasion. So far no deposits certainly attributed to this early ice flow are known in the state. Many changes, especially drainage modifications, are apparent in wide areas, are sufficiently old in point of physiographic history and are difficult to account for on any other assumption than the effects of an early glacier. Deposits assigned to the Jerseyan, or to a sheet much older than the Illinoian, are present in New Jersey, in east central Pennsylvania and locally in northwestern Pennsylvania.[1] Such deposits are considered correlative with strata of an early sheet in the Mississippi Valley.

In Ohio this early drift sheet appears to have not seriously modified any of the streams, such as the Pittsburgh, and Dover rivers flowing northward to the Lake region, but to have completely blocked the western course of the Teays. The eastern streams in passing from Teays to Deep Stage time simply settled down deeper in their course with only slight modifications.

The Teays River, however, was completely dammed in its lower course, with the result of flooding in the main valley and in those of all the larger tributaries. This was especially true of the streams in southern Ohio. Such valleys became long finger lakes. It was during this time that the Minford silts were deposited from the fine materials long held in suspension and carried into the basin from headwater areas, some far out into the Piedmont Plateau. Such silts in southern Ohio are found at elevations as high as 840 feet and are thus plastered well up on the valley walls of these old streams the relief of which was from 250 to 300 feet, the usual position below the Lexington peneplain. Eventually through continued ponding

[1]Leverett, Frank. Glacial Deposits in Pennsylvania. *Pennsylvania Topographic and Geologic Survey*, Bulletin G 7, 1934.

the waters broke over low divides or cols and soon established a new system of drainage bearing little resemblance in direction or pattern to the older Teays system. This second cycle of drainage is known as the Deep Stage on account of the depth of cutting of the valleys.

UPLIFT AND REJUVENATION

Soon after the new system of drainage was outlined regional uplift took place with consequent active cutting of stream beds. Through this the stream floors were degraded much below the level of the Teays. At Wheelersburg where the Teays and Cincinnati rivers, both major streams, were in contact, the difference is 190 feet, the floor of the former standing at 650 feet, and that of the latter at 460 feet. This uplift, regional in extent, took place rather rapidly as the streams cut deep narrow valleys, a feature characteristic of this cycle of erosion. Compared to Teays the time interval of the Cincinnati cycle of erosion was not long as the streams of the latter were unable to widen the valleys, to deepen them headward, or to lower the bordering hills. During the period, however, much work was done as the major streams cut deep narrow valleys through thick deposits of resistant rock.

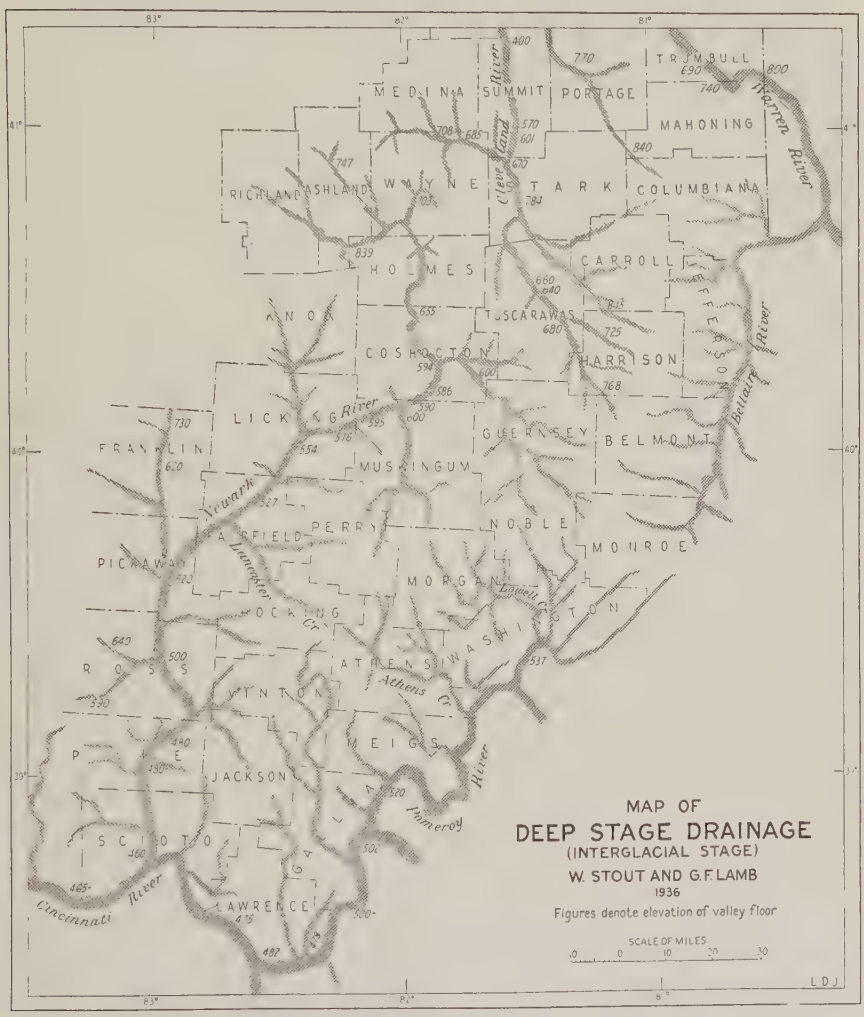
DEEP STAGE DRAINAGE

The Deep Stage drainage was first defined by Coffey and later detailed in parts by Ver Steeg, Lamborn, Lamb, Scranton, Happ, White and others. This cycle of erosion is interglacial in that it was inaugurated by an early ice sheet, possibly Jerseyan, and brought to a close by the Illinoian. Its main features are the development of many new streams especially in the old Teays basin, the deepening of all channels below the former levels, and the general immaturity of basin reduction. The important streams of Deep Stage time that drained southern Ohio are next considered. (See map of Deep Stage Drainage.)

CINCINNATI RIVER

The master stream of the area, which for clearness may be called the Cincinnati, received its waters almost entirely from the basin formerly drained by the Teays. This area includes that within the present basins of New, Gauley, Little Kanawha, Kanawha, Big Sandy, Little Sandy and others in southwestern Virginia, West Virginia, and eastern Kentucky,

and within those of the Muskingum, Hocking, and Scioto rivers in Ohio. The headwaters of the Cincinnati River need not be discussed here. From Charleston, West Virginia, the course was not along that of the Teays but along that of the



present Kanawha to Point Pleasant. Here the new stream turned southwestward following within the basin but not along the direct course of the older Marietta River to Gallipolis, thence across a divide into the old Teays valley again at Huntington. From Point Pleasant to Huntington this is the

route of the present Ohio. From the latter place the Cincinnati River turned northwestward and closely followed the course of the Teays to Wheelersburg, thence across a divide to the old Portsmouth River, thence across another divide into an old basin of Teays time. Thus from Huntington the course was that of the present Ohio past Ironton, Portsmouth, Manchester and Maysville to Cincinnati, and thence on westward to the interior basin, where it finally discharged its waters into the Gulf of Mexico. The floor of the Cincinnati has an approximate elevation of 360 feet at Cincinnati, 460 feet at Portsmouth, 480 feet at Kenova, and 490 feet at Point Pleasant.

NEWARK RIVER

The Newark River as defined by Lamborn and other workers was an important tributary of the Cincinnati River and drained a large area in central and south central Ohio. This stream gathered its headwaters in part in the basin of the old Cambridge River and along that portion of the present Tuscarawas to the old divide at Gnadenhutten, which barrier separated the north-flowing from the west-flowing streams. Near Coshocton the Newark River received an important tributary from the north the basin of which is now drained by Killbuck Creek and the Walhonding River. The main stream thus formed by such contributions then flowed southwestward to Conesville, thence westward along the present Muskingum to Trinway, thence westward through the conspicuous abandoned valley past Frazeysburg and Black Run to Newark where the course is less evident through deep burial by glacial drift. As shown by Lamborn, the main stream received at Newark an important tributary from the north, then flowed southwestward past Buckeye Lake, Basil and Carroll to Circleville where other tributaries were received from the north. From Circleville the course of the Newark River was southward, along the present Scioto, past Chillicothe, Richmondale, Waverly and Piketon to Portsmouth, where it joined the master stream, the Cincinnati River. From Chillicothe to Waverly the Newark River flowed in reverse direction to the Teays and from Waverly to Portsmouth in reverse to that of the Portsmouth. The floor of the Newark River has an elevation of approximately 480 feet at Waverly, 500 feet at Chillicothe, 520 feet at Circleville, 521 feet at North Baltimore, 541 feet at Buckeye Lake, 554 feet at Conesville and 594 feet at Coshocton.

The Newark River had many small tributaries, a few of which may be mentioned. One began near the Morgan-Muskingum County line, flowed northward past Philo, Zanesville and Dresden to the main stream at Trinway. Another branch of some importance began at the divide near Nelsonville, flowed northward past Haydenville, Logan, and Lancaster, and united just north of Carroll with the Newark River. The course of another Deep Stage stream is quite apparent from South Bloomingville westward to Laurelville. Important tributaries, now deeply buried by drift, were received from the north at Circleville and from the west at Chillicothe. The Newark River and its tributaries are responsible for much physiographic history of interest in central and southern Ohio.

POMEROY RIVER

A stream of Deep Stage time of importance in southern Ohio is what may be called the Pomeroy River from the name of the place in Meigs County past which it flowed. This stream gathered its headwaters west of the Flushing escarpment in the Lexington peneplain area in southern Monroe, southern Noble, and eastern Washington counties. It flowed within the basin of the Marietta River of Teays time but instead of following closely the older course it carved a new way well up on the rim of the depression. The course was that now taken by the present Ohio from Marietta past Parkersburg, Ravenswood, Racine and Pomeroy to Point Pleasant where it united with the Cincinnati River. Tributary divides were near Sardis on the present Ohio River, at the Morgan-Muskingum county line of the Muskingum River, and at the Athens-Hocking county line on the Hocking River.

CLEVELAND RIVER

The Deep Stage Cleveland River drained, in the main, the basin of the Teays Stage Dover River. In the headwater areas little change was made during the second cycle except deepening the channels some 200 feet below the former level. These streams were deeply entrenched, had steep abrupt walls, and were immature in gradation and dissection. The major stream has been well traced by Ver Steeg and others northward from Uhrichsville past Dover, Massillon and Barberton to Lake Erie at East Cleveland. It gathered its headwaters, north and west of the Flushing escarpment, in

northwest Belmont, northeast Guernsey, western Harrison and southeast Tuscarawas counties in territory reduced mainly to the level of the Lexington peneplain but within the basin of the north-flowing streams. The Cleveland River shows abnormalities in character of gradient, depth of channel, and character of fill.

WARREN RIVER

The Deep Stage cycle of stream development in eastern Ohio and western Pennsylvania consisted, in the main, of simply deepening the courses of the older Teays cycle as the limits of the basins and as the general direction of the courses remained much the same in both. Only minor changes are evident. Throughout the entire area the streams still have Deep Stage characteristics: that is, they have narrow valleys with steep walls, have few laterals, and have not prominently reduced the bordering hills.

The main stream was what may be known as the Warren River. Its course was quite the same as that of the Pittsburgh River, that is northward from Pittsburgh, past Beaver Falls, New Castle, Hubbard and Youngstown to Warren where it is deeply buried by drift. From Warren the stream appears to have flowed on northward to Lake Erie. The tributary receiving drainage from southeastern Ohio for identification is called the Bellaire River. Throughout this area the Teays and Deep Stage cycles of erosion were continuous or without a definite break, the definition coming from changes and influences at work elsewhere.

Illinoian Glaciation

GENERAL STATEMENT

One of the important factors in changing the physiography of Ohio was the Illinoian glacier which had a marked influence in leveling the surface, through burial by drift, of about three-fifths of the state and further in changing the drainage systems throughout the entire area. The position of the Illinoian ice front in northeastern Ohio is not known as the later Wisconsin drift pushed farther south and thus obliterated the evidence of the preceding sheet. The Illinoian drift is first evident near Loudonville in Ashland County. From here the border of this drift extends southward past Brinkhaven, Knox County; New Guilford, Coshocton County; Hanover, Licking County; Gratiot,

Muskingum County; Fultonham and Junction City, Perry County; Sugar Grove, Fairfield County; Haynes, Hocking County; Chillicothe and Bainbridge, Ross County; Cynthiana, Pike County; Belfast, Highland County; Seaman, Adams County, to the Ohio River at Ripley, Brown County.

The Illinoian was a thick sheet of glacial ice and hence had much influence both directly and indirectly in shaping surface features. It completely obliterated the Deep Stage drainage in the area passed over and was effective in revamping much of that in a wide area south of its border. It also left great quantities of glacial debris—drift, outwash, etc.—for weathering agencies and stream forces to work upon. This condition was much different from that in pre-Illinoian time where the mantle was only decayed rock and the stream burden only the wash from the hills. South and east of the glacial border the chief work caused through the Illinoian drift was stream modification.

Post-Illinoian Drainage Stage

GENERAL STATEMENT

The answer to the question of whether or not the Illinoian glacier blocked the northward passage of the Cleveland and Warren rivers is uncertain. The chief evidence, however, supports the view that these streams continued undisturbed during the time between the Illinoian and the Wisconsin ice sheets. The older glacier certainly obliterated by burying with a thick mantle of drift the Newark drainage of central Ohio from Hanover to Chillicothe and the Cincinnati River from Ripley to Cincinnati. As this ice was an effective barrier the waters from the unglaciated portion of southeastern Ohio and from large areas in the states to the south sought other outlets and thus established new lines of drainage. (See map of Post-Illinoian Drainage.)

NEW MARTINSVILLE RIVER

In this area the master stream of the post-Illinoian and pre-Wisconsin period, which for definition may be called the New Martinsville River from a place near the col, occupied much the same valley as that of the Ohio of today except that the older stream was reversed in flow. The ice barrier at Ripley completely obstructed drainage to the westward.

Further, no passage ways are evident south of the drift border in the uplands of Kentucky. The ice obstruction resulted in vast ponding of water east of the ice front in all the valleys of the Deep Stage streams. New outlets were a natural consequence. Eventually the flood waters rose to such a height that they found an opening through a low divide or col near Sardis then continued down the Steubenville and Warren rivers and finally reached the sea to the east. This change was affected apparently with no great amount of work. Some cutting was necessary through the highlands at the Sardis col and through the upper course of the Steubenville River. Along many of the older valleys, however, filling took place as the floors of the new rivers were much above the level of the preceding Deep Stage streams. Through these changes the New Martinsville River thus received the drainage of southeastern Ohio, northeastern Kentucky, central and western West Virginia and parts of western Virginia.

POST-ILLINOIAN MUSKINGUM RIVER

The Illinoian ice sheet at this time thus gave rise to the shaping of the present Muskingum and Hocking rivers by forcing the flood waters over low divides from one basin to another. The Newark drainage system from Hanover to Chillicothe was completely buried by the ice. This obstruction so ponded the headwaters of the Newark River that a new way was opened across the col at the Morgan-Muskingum county line, thus uniting in one stream the old north-flowing river and the south-flowing river. The result of this change was the post-Illinoian Muskingum River which, with some modifications through the later Wisconsin drift period, has remained to the present time.

The ice dam at Sugar Grove caused a discharge of the waters of the small basin of Lancaster Creek over a low divide near the Athens-Hocking county line, close to East Clayton, and then down the Deep Stage Athens River to the major stream, now flowing eastward. Here also little new work was required to make the change as the dividing ridge was low and narrow, as the older streams were deeply trenched well toward their headwaters and as the floor of the new stream was raised, through filling with silt, sand and gravel, to a level much above that of the older one. This post-Illinoian Hocking River thus created has undergone no radical changes since that time. The later Wisconsin cycle of glaciation and erosion made some modifications, mainly through filling.

POST-ILLINOIAN SCIOTO RIVER

The part of the Deep Stage Newark River from Chillicothe to Portsmouth was not materially changed in course during Illinoian time. The work consisted mainly in filling the valley quite deeply with outwash material and thereby raising the floor level. Some side streams, however, were considerably

modified. Salt Creek in Western Hocking and western Vinton counties was shaped at this time. The ice dam at Haynes deflected the waters of several small streams over a col in Section 36, Salt Creek Township, Hocking County to a stream draining to the wouthwestward. At this time local changes were effected in the lower course at Salt Creek. Brush Creek in central Adams County was altered at this time in parts of its course.

Wisconsin Glaciation

GENERAL STATEMENT

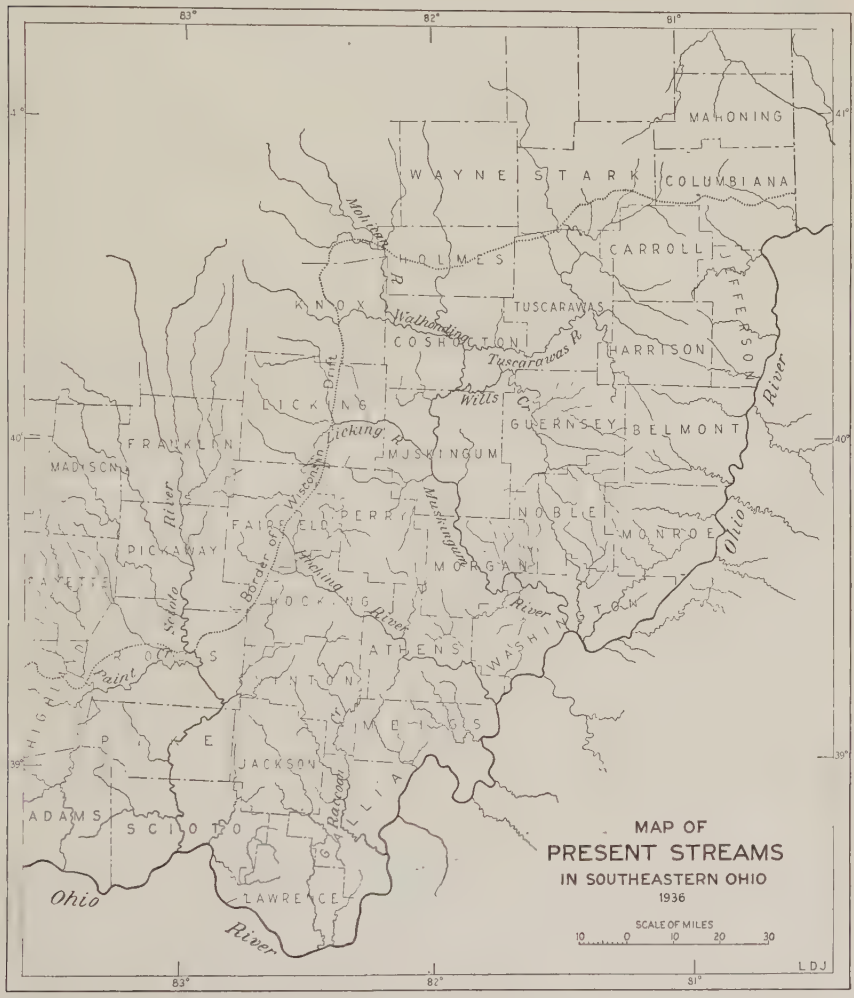
The last great ice sheet to invade Ohio was the Wisconsin glacier, the deposits of which are apparent over about two-thirds of the state. It made many changes in the surface features, leveling certain areas to a smooth plain, piling up drift in others to knobby hills, and filling certain valleys with great quantities of outwash materials. In eastern Ohio the Wisconsin ice sheet extended about one-third of the way across the state, whereas the older Illinoian is considered to be absent or as yet is not definitely recognized. Throughout the central part of the state the two borders are not widely separated, the younger lagging a little behind the older. In western Ohio the conditions are quite different. Here the Illinoian passed south of the Ohio River, whereas the Wisconsin lacked from 15 to 40 miles of reaching this line of drainage. The border of the Wisconsin ice is defined, in a general way, by a line from Clarkson, Columbiana County, westward through North Industry, Stark County; Wilmot, Tuscarawas County; Millersburg, Holmes County; Loudonville, Ashland County, to near Lexington, Richland County. At the latter place the terminal boundary turns southward, through nearly a 90° angle, and extends through Gambier, Knox County, to Chillicothe, Ross County. Another change in direction here deflects the border westward through Rainsboro, Highland County; Martinsville, Clinton County; Hamilton, Warren County, and Lockland, Hamilton County, to the Ohio-Indiana line near the village of Harrison.

The Wisconsin appears to have been a somewhat thicker or more massive ice sheet than the older Illinoian as is indicated by the accumulations left in typical areas. It was certainly an effective barrier in blocking drainage along its front, produced large floods of water for stream work, and yielded great quantities of silt, sand and gravel for outwash deposits along streams that lead out from the border. Beyond the ice border the period was more constructive in building up new deposits than destructive in tearing down old ones. Many changes were thus effected both through the direct action of the glacier in the area passed over and through its secondary modifications far out into the driftless region. Drainage alterations were important.

Present Streams

GENERAL STATEMENT

The chief effects of the Wisconsin glacier on the streams of the driftless area of southern Ohio and of adjacent parts of



the bordering states were, first, changes of direction of flow through blocking some of the older lines of drainage and through the opening of other passages and, second, choking the adjacent valleys with silt, sand and gravel, thus causing the new streams to flow at higher levels. The courses of the present streams

in southeastern Ohio are on this account more or less composite in make-up, some much so. Work may have been done through Teays, Deep Stage, post-Illinoian or post-Wisconsin time or through most any combination of these. The Ohio Valley for example is the result of some action throughout each of these degradation periods. (See map of present streams.)

OHIO RIVER

The ice advanced southward to the middle of the state in western Pennsylvania and to a line through central Columbiana, southern Stark, northern Tuscarawas, central Holmes, southern Ashland and southern Richland counties in Eastern Ohio. It thus completely obliterated the northern passages of the old Warren and Cleveland rivers, making necessary changes in the headwater drainage. The waters from the basin of the Warren River in Pennsylvania and West Virginia and that from the New Martinsville River—draining through the Warren—in southern Ohio, West Virginia and eastern Kentucky were thus forced by the ice dam near Ellwood City, Pennsylvania, to find a new way to the sea. As the Wisconsin glacier did not reach in southwestern Ohio, the old valley of the Deep Stage Cincinnati River with its thin veneer of Illinoian drift, this outlet was reopened and the Ohio River as we know it today took outline with the flow of water to the west. Much of the work involved in this change was simply filling and regrading.

TUSCARAWAS RIVER

Burial of the lower part of the basin of the old Cleveland River by the Wisconsin glacier with stagnation of the headwaters appears to be the most plausible explanation for the peculiar shifts of the present Tuscarawas River from Bolivar to Coshocton. Through ice advancement the waters from the Sandy Creek basin were deflected southward, towards Zoar, in wide valley of the older north-flowing stream. Then this flood of water increased by that from Conotton Creek were forced over a col to the westward and thus cut the gorge-like valley from Zoarville to Dover. The old divide was located near the present Dover dam. This constricted valley, so new in appearance, most probably was cut late in the advance of the Wisconsin ice sheet.

From Dover to Tuscarawas village the present Tuscarawas River flows in reverse direction to that of the old Cleveland River and at a much higher level. The accumulated waters from Sandy and Conotton Creeks with that from the upper courses of Stillwater Creek were sufficient to flow headward up a tributary of the post-Illinoian Muskingum River which provided an outlet to the master stream, the Ohio River. This passage way, however, is not like others of known recent origin. The valley from Tuscarawas village to Coshocton has about normal width and its floor is quite deeply degraded. In these respects this part of the valley more nearly resembles the work of a Deep Stage than a Wisconsin Stage Stream.

MUSKINGUM RIVER

As the post-Illinoian Muskingum River proper was not reached by the Wisconsin ice no important modifications were necessary to take care of the waters from the melting ice. The main work accomplished was in discharging much outwash, silt, sand and gravel, for thick deposits along the valley. These accumulations are now represented by the high-level terraces very evident locally from Coshocton to Marietta.

HOCKING RIVER

The post-Illinoian Hocking River was beyond the influence of major changes through the Wisconsin glacier. Only the headwater streams were directly affected. The valley, however, received some contribution in the way of outwash materials. Further, a few shifts in the line of drainage appear, the most important being new ways near Rockbridge in Hocking County and at "The Plains" in Athens County.

SCIOTO RIVER

The Wisconsin ice pushed southward to Chillicothe obliterating of course all drainage lines north of this place. As the post-Illinoian Scioto valley from Chillicothe to Portsmouth was especially wide and open—the work of both Teays and Deep Stage erosion—the main accomplishment from the last ice invasion was the piling up of additional masses of silt, sand and gravel, locally a hundred or more feet in thickness. These deposits are now represented in the high terraces along the valley walls.

TERRACES

One of the results of the ice invasions is that the present streams are in general degrading in character, that is, they are still busily engaged in removing this filling of outwash material. Through such action many fine terraces are found along these valleys. From one to four well defined terraces may be recognized. This is especially true along the Ohio River across the reach of the state, along the Tuscarawas-Muskingum from Zoar to Marietta, along the Hocking from Lancaster to Hockingport and along the Scioto from Chillicothe to Portsmouth.

SUMMARY

The physiography of Southeastern Ohio thus presents a story with the degrading agencies of nature, with rock strata of different kinds and various densities, with uplifts by the great forces that build land surfaces and with repeated glaciation with profound modifications as the prime factors in leaving a surface with a multiplicity of features that attract attention and call for explanation. Few other regions are so rich in a jumble of markings of natural events. Many contributing elements are far from clear but this uncertainty adds to the interest of the story and allows for new interpretations by other workers. Southeastern Ohio thus offers much for the student of physiography, geology, botany, biology and kindred sciences.

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COPPER SOLUTIONS FOR MICROSCOPICAL DETECTION OF GLUCOSE AND FRUCTOSE*

ELIZABETH S. BRETZ

PROBLEM

A number of copper reagents have been proposed for distinguishing glucose from fructose. Since the distinction depends upon the relative rate of oxidation of the two sugars, the tests will necessarily be influenced by concentration of sugar, time, temperature, and concentration of reagent. For a microscopical detection of these sugars, the problem therefore is to find the temperature and time of reaction at which these sugars may be most readily distinguished when they occur at different concentrations. Methyl fructosazone may be used to distinguish glucose from fructose; but because the copper tests are much more sensitive for microscopical work, it seems important to have more definite knowledge about their possibilities and limitations.

REAGENTS

The copper reagents proposed by Ost, Pieraerts, and Benedict for macroscopical tests and the one proposed by Flückiger for microscopical tests for sugars in plant cells were employed. A brief account of the composition and of the results reported for these reagents follows.

1. *Flückiger's copper tartrate reagent* (2, p. 272). Copper tartrate is prepared by mixing a solution of 30 gm. copper sulfate in 300 cc. hot water with a solution of 70 gm. potassium sodium tartrate in 200 cc. hot water. The precipitate is filtered, dried in a desiccator, and kept in a brown bottle. For each separate test a few crystals of copper tartrate are placed on a slide in a drop of 20 per cent sodium hydroxide. When the copper tartrate has dissolved, a drop or small section of the material to be tested is added. According to Flückiger (2, p. 272), reduction by fructose occurs immediately at room temperature and by glucose very soon with slight warming.

In order to have a uniform reagent for comparative tests the procedure may be modified by preparing standard solutions. If the latter procedure is followed, the solution should be renewed daily, as autoreduction slowly occurs in the solution. Since autoreduction increases with an increase in concentration of copper tartrate in the reagent, the amount of copper tartrate present should not greatly exceed the amount necessary to oxidize the sugar in the test object.

*Papers from the Department of Botany, The Ohio State University, No. 389.

Lampe (6, p. 347), by using a "sky-blue" solution, obtained the maximum amount of cuprous oxide with fructose in 7 minutes at room temperature and with glucose in 3 minutes at 45° C. The solutions used in the present tests were 0.05 gm. copper tartrate in 10 cc. of 20 per cent sodium hydroxide and 0.05 gm. copper tartrate in 20 cc. of 20 per cent sodium hydroxide.

2. *Ost's copper carbonate reagent* (7, p. 840, footnote 2). To 700 cc. boiling water 250 gm. potassium carbonate is gradually added. To that solution 100 gm. potassium bicarbonate is slowly added until it completely dissolves. A solution of 17.5 gm. copper sulfate in 100 to 150 cc. water is then added under vigorous agitation. After cooling, the solution is made up to 1000 cc. and filtered. Klein (4, p. 779) says this reagent reduces with gentle warming only ketoses. Zerban and Sattler (8, p. 307) made macrochemical tests using Nijns' modification of the above solution. This contained 15 gm. copper sulfate instead of the 17.5 gm. used by Ost. They placed 20 cc. sugar solution—containing not over 0.3 per cent fructose—in 50 cc. of the copper reagent previously warmed in a small Erlenmeyer flask to 48.5° C. to 49° C. After 2.5 hours at that temperature the cuprous oxide obtained was weighed. Zerban and Sattler (8, p. 308) found that with about equal quantities of glucose and fructose, 1 mg. of glucose reduces about one-thirteenth the amount of copper reduced by 1 mg. of fructose. The reducing effect per mg. of glucose decreases as the concentration of glucose increases, and also as the concentration of fructose in the mixture increases.

3. *Pieraerts' modification of Ost's reagent* (7, p. 840). The solution is prepared in the same way as Ost's reagent, but the amounts of the salts are changed to 140 gm. potassium carbonate, 100 gm. potassium bicarbonate, and 15 gm. copper sulfate. The reagent deposits basic copper carbonate after 24 hours. It must be renewed weekly (7, p. 851). Tests made by Pieraerts in the cold (13° C. to 16° C.) were examined every 15 minutes during the first 6 hours, thereafter on the ninth, twelfth, and twenty-fourth hours (7, p. 837). According to Pieraerts, in the cold glucose does not reduce the reagent in 24 hours, while 4 to 5 per cent fructose reduces it in 1 hour, 3 per cent in 1.5 hours, 2 per cent in 2 hours, and 1 per cent in 2.25 hours. Pentoses cause reduction in 4 hours in the cold (7, p. 842). Tests made by Pieraerts on a water bath were examined as reduction became evident. At the end of 1 hour the tests were concluded (7, p. 837). He states that glucose gives no precipitate of cuprous oxide at 30° C., 35° C., 40° C., or 45° C. Above 50° C. there is reduction (7, p. 842). At 30° C. 1 to 5 per cent fructose reduces the reagent by the end of 1 hour. Pentoses cause no reduction at this temperature in 1 hour, but at 35° C. they do reduce the reagent in 1 hour (7, p. 843). Pieraerts summarizes (7, pp. 846-847) the use of his modification of Ost's solution by saying that it can distinguish 1 to 5 per cent free fructose in the presence of other natural sugars, pentoses excepted, by heating 1 hour at 35° C. If pentoses are present, it is still possible to identify free fructose in 2.5 hours in the cold, or in 1 hour at 30° C. One is surprised, then, to read Pieraerts' statement (7, p. 847) that the diagnosis of fructose is

impossible if less than 20 per cent of that hexose is present, especially if pentoses are also in the mixture.

4. *Benedict's copper citrate reagent* (1, p. 486). A solution is made of 173 gm. sodium citrate and 100 gm. anhydrous sodium carbonate by heating in 600 cc. water. This is filtered if necessary and made up to 850 cc. A solution of 17.3 gm. copper sulfate in 100 cc. water is diluted to 150 cc. The copper sulfate solution is poured slowly with constant stirring into the carbonate-citrate solution. The mixture is ready for use and does not deteriorate on standing. It is not caustic and may be kept in cork or glass stoppered bottles. Upon reduction the solution is apt to yield green or yellow hydrated cuprous oxide, rather than the red anhydrous oxide.

Kolthoff (5, p. 888), working with 1 cc. sugar solution in 5 cc. of Benedict's reagent, could distinguish 1 per cent fructose from glucose and lactose after heating 0.5 hour at 37° C. to 40° C., but with 0.5 per cent the distinction was doubtful. At room temperature for 24 hours 0.5 per cent fructose was distinctly evident, 0.2 per cent gave a very slight reaction, and 0.1 per cent gave no apparent test. According to Klein (4, p. 780), copper solutions containing citric or tartaric acid are extremely photosensitive. Before beginning a test it should be determined whether autoreduction has occurred.

5. *Pieraerts' copper-glycocol reagent* (7, p. 841). To a solution of 12 gm. glycocol in hot water one adds little by little 6 gm. freshly prepared cupric hydroxide, which dissolves almost completely after 15 minutes on a steam bath. The solution, cooled to 60° C., is added to 50 gm. potassium carbonate, made up of 1000 cc., and filtered. The liquid keeps very well. If the potassium carbonate is added at a temperature higher than 60° C. there will be a precipitate of carbonic anhydride, which greatly diminishes the sensitivity of the reaction.

In the preparation of cupric hydroxide for the above reagent certain precautions are necessary to prevent its immediate oxidation. Add 5 per cent of ammonium chloride to 5 per cent copper sulfate solution. Pour this into 20 per cent sodium hydroxide. Wash the precipitate on a Buchner funnel with cold water. Keep the funnel covered to prevent oxidation. Drying the precipitate in an oven will hasten oxidation. It is best to dry the precipitate on a suction filter, weigh, and use it immediately.

Pieraerts (7, p. 845) says that free fructose forms an abundant precipitate of cuprous oxide in the cold after 24 hours and is the only natural sugar which does so. The results are uncertain with heat. One cannot trust the indications at 30° C. for an hour, if more than 3 per cent fructose is present.

METHODS

The concentrations of glucose and fructose used were 0.1 per cent, 0.5 per cent, 1 per cent, 5 per cent, and 10 per cent. The three temperatures used were room temperature, 40° C., and that of a steam bath. Slides at room temperature were kept in a moist chamber to prevent drying. One drop of sugar solution was thoroughly mixed with two drops of copper reagent on a microscopic slide.

Accurate counts were made of the cuprous oxide crystals obtained in each test. A description of the method of counting is not included in this paper, since the objective is chiefly to indicate with which reagents differentiation between glucose and fructose can be obtained.

In Flückiger's reagent it was not known what proportions of copper tartrate and sodium hydroxide would give the best results. Two solutions were tried, 0.05 gm. copper tartrate in 10 cc. of 20 per cent sodium hydroxide solution, and 0.05 gm. copper tartrate in 20 cc. of 20 per cent sodium hydroxide solution. The first solution did not give differentiation between 10 per cent glucose and fructose. The solution of 0.05 gm. in 20 cc. gave differentiation at all concentrations at room temperature.

DISCUSSION

The following paragraphs point out discrepancies in the results of the present microscopic tests and the results of the macroscopic tests mentioned in the section on reagents.

Ost's copper carbonate reagent was not found to reduce "only ketoses" with gentle warming, as reported by Klein, although at 40° C. there was good differentiation between the sugars at all concentrations.

Pieraerts' modification of Ost's reagent was found to be reduced by glucose to some extent at room temperature and at 40° C., contrary to the macroscopical observations of Pieraerts. It should be noted, however, that Pieraerts' room temperature was 13° C. to 16° C., while that of the present tests was about 25° C.

Benedict's copper citrate reagent gave differentiation between glucose and fructose at 0.1 per cent and 0.5 per cent at room temperature and at 40° C. when used in microscopical mounts, whereas Kolthoff, working macroscopically, failed to find differentiation at these low concentrations, except in the case of 0.5 per cent at room temperature.

Pieraerts' copper-glycocol reagent, recommended by Pieraerts for use at room temperature in distinguishing fructose from glucose, failed to do so in the present tests at 0.5 per cent and at 1 per cent. Even more cuprous oxide was reduced by glucose than by fructose in some cases. Differences in the size of the crystals obtained made it difficult to compare the amount of precipitate.

SUMMARY OF RESULTS

1. Five copper reagents were tested at the temperature of a steam bath, at 40° C., and at room temperature as to their use in distinguishing between 0.1 per cent, 0.5 per cent,

1 per cent, 5 per cent, and 10 per cent glucose and fructose in microscopical mounts.

2. None of the reagents gave positive tests only for fructose. Positive tests for glucose varied from zero to a copious precipitate, depending upon the temperature and concentration of the sugar.

3. Each of the reagents may be used for distinguishing glucose from fructose under certain conditions of temperature and concentration of the sugars.

4. All except Pieraerts' copper-glycocol reagent gave differentiation between glucose and fructose at room temperature at all concentrations. None of the reagents gave differentiation with steam at all concentrations. Flückiger's copper tartrate reagent and Pieraerts' copper-glycocol reagent failed to give differentiation at 40° C. at all concentrations.

5. Table I indicates the time interval in relation to different temperatures at which the reagents are useful in distinguishing between glucose and fructose at different concentrations.

TABLE I

DIFFERENTIATION BETWEEN GLUCOSE AND FRUCTOSE

REAGENT AND TEMPERATURE	TIME IN MINUTES AT WHICH DIFFERENTIATION APPEARS				
	CONCENTRATION OF SUGAR SOLUTION				
	0.1 per cent	0.5 per cent	1 per cent	5 per cent	10 per cent
Flückiger's Room Temp.	15–60..*	4–15	4–60..	4–60..	4–60..
Ost's Copper Carbonate					
Steam bath	¼–2..	¼–2..	¼–2..		
40° C.	30–60	30–60	15–60	5–1440..	5–1440..
Room Temp.	120	1440..	120-1440..	60–1440..	60–1440..
Pieraerts' Modification of Ost's.					
Steam bath	½–1..	½			
40° C.	30–60..	15–60..	10–60..	5–60..	2–60..
Room Temp.	30–120..	15–120..	15–120..	15–120..	7–120..
Benedict's Copper Citrate.					
40° C.	10–60..	5–60..	5–60..	5–60..	5–60..
Room Temp.	60..	60..	60..	60..	30–60..
Pieraerts' Copper-Glycocol.					
40° C.		60	30–60	10–60	10–60
Room Temp.	1440..			60	10–60

*Two periods (..) after a figure indicate that no tests were made for a longer time interval. Where there are no periods the last figure given is the longest time interval in which there was good differentiation, as shown by further tests.

The writer wishes to express her appreciation to Dr. H. C. Sampson, of the Department of Botany of The Ohio State University, for his assistance in the direction of the experimental work and in the preparation of this paper.

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The Fungi

Students of mycology and plant pathology will find the enlarged second edition of this text especially useful. It enables the student to visualize the entire fungus field and the relationship of one order to another. It is probably too advanced for most undergraduates.

Early in the text the authors define and limit the use of the technical terms which are later employed in the discussion of asexual and sexual reproductive structures. An excellent chapter, such as is seldom found in texts by American authors, on the physiology of saprophytism, parasitism and symbiotic relationships, is included. The author discusses the reproductive structures of each important order in sequence, beginning with the Archimycetes of the Phycomycetes. Many American mycologists place the Archimycetes in a separate class, but in this text they are included in the Phycomycetes as a sub-class of equal rank with the Oomycetes and Zygomycetes. Other minor changes in classifications exist, but one might expect British mycologists to have different viewpoints from ours on the relationship of some of the fungus groups.

Usable keys whereby the student may readily distinguish the different orders are found throughout. The volume is well illustrated by author's drawings and by figures reproduced from publications of mycologists past and present.

In the concluding chapter mycological techniques such as isolation, single spore culture, and the use of fixatives, stains, and the various types of media are discussed. The citations are well chosen and appear to be entirely adequate, in as much as there are forty pages of them. The book is lucidly written and, taken in its entirety, has many commendable features. It is printed on a good grade of paper and is securely bound.—*A. L. Pierstorff.*

The Structure and Development of the Fungi, by H. C. I. Gwynne-Vaughan and B. Barnes. xvi+449 pp. Cambridge at the University Press, in New York, the MacMillan Company, 1937. $5.50.

STUDIES OF THE GENUS EMPOASCA[1] (HOMOPTERA, CICADELLIDAE)

Part V

Twelve New Species of Empoasca from the United States

RALPH H. DAVIDSON AND DWIGHT M. DeLONG
The Ohio State University

A continuation of the study of the Genus *Empoasca* has brought to light several species which have apparently not previously been described. The present group of species contains material from various portions of the United States.

Empoasca mucronata n. sp.

Resembling *pyramidata* but with more narrowed apical portion of pygofer spine. Length, 4 mm.

Vertex produced and bluntly rounded, almost twice as wide between eyes as median length, produced one half its length before anterior margin of eyes.

Color: Pale to dull green, often marked with the three pale longitudinal stripes on the vertex, the three pale spots on anterior margin of pronotum and the median broad pale stripe on the scutellum.

Genitalia: Male plates narrowed on apical half and with narrow rounded apices. Lateral processes curved concavely outward with the apices directed outwardly. Pygofer spine with a broad, short basal portion at the caudal ventral edge of which a short narrow spine arises and is directed ventrally.

Holotype male, Pickaway Co., Ohio, June 24, 1934 (J. S. Caldwell), in DeLong collection. Paratype males same locality and date and Oakwood, Illinois, Aug. 17, 1934 (DeLong and Ross), in DeLong collection and Illinois Natural History Survey collection.

Empoasca curvatura n. sp.

Resembling *pyramidata* and *distracta* but with aedeagus more enlarged at apex and pygofer spine more narrowed apically. Length, 3.2 mm.

Vertex produced, bluntly angled, twice as wide as median length, produced almost one half its length before anterior margin of the eyes.

Color: Dull green with three white longitudinal areas on vertex and three anterior white spots on anterior margin of pronotum. Scutellum with broad longitudinal median white stripe and a transverse band just before apex.

Genitalia: Female last ventral segment broadly roundedly produced. Male plates rather long, apices blunt and narrowed. Lateral processes

[1]Previous studies of the group are summarized in Ohio Journal of Science 36: 225, July, 1936, and 32: 29, January, 1935.

curved concavely outward and overlapping near apex. Pygofer spines rather short, abruptly narrowed and produced into a ventrally directed apical spine. Anterior margin concavely, broadly notched.

Holotype male from Taylor Falls, Minnesota, August 16, 1916 (DeLong), allotype female, Urbana, Illinois (Jones) and paratype males and female from Urbana, Illinois (Jones) and Athens, Ohio (Stehr) in the DeLong collection.

Empoasca orthodens n. sp.

Resembling *bifurcata* in general appearance and internal male genitalia, but with a distinct pygofer spine. Length, 3.5 mm.

Vertex rather strongly produced and bluntly angled. Two-thirds as long at middle as basal width between eyes. Produced two-thirds its length before anterior margins of the eyes.

Color: Dull yellowish-green. Vertex with a pale blotch next either eye. Pronotum with three pale spots on anterior margin.

Genitalia: Male with long plates, apices rounded and slightly diverging. Lateral processes of pygofers curved concavely outward, apices rather abruptly narrowed and narrowly produced for a short distance. Pygofer spine rather long curved caudally and dorsally forming a spine like apex. Also a short straight spine arising ventrally and extending ventrad.

Holotype male from Putnam, Illinois, collected by Ross and DeLong July 6, 1934, in the collection of the Illinois Natural History Survey.

Empoasca bicuspida n. sp.

Resembling *bifurcata* and *orthodens* but smaller in size and with shorter posterior spine of the bifurcate pair and different lateral processes. Length, 3 mm.

Vertex produced and rounded at apex, a little wider between eyes than length at middle. Almost as long at middle as basal width between eyes.

Color: Dull green, often washed with golden yellow without pale markings. Anterior margin of pronotum often with three pale spots.

Genitalia: Female last ventral segment with posterior margin roundedly produced. Male plates rather narrow, tapered and bluntly pointed. Lateral processes vermiculate as in *bifurcata*. Pygofer spines with bifurcate apex, the posterior spine of the bifurcate pair comparatively short.

Holotype male and allotype female Belle Glade, Florida, 1929 (Clifton) in the DeLong collection. Paratype male and female specimens from Spavina, Oklahoma, St. Petersburg (Osborn), Gainesville (Osborn), Cocoanut Grove (Breakey), Miami (Breakey), Dade Co. (Breakey), and Belle Glade (Clifton), Florida, in the DeLong, Osborn and Breakey collections.

Empoasca latarca n. sp.

Resembling *bifurcata* but more robust and with lateral processes and spine of pygofer more like those of the species of Kybos. Length, 3.5 mm.

Vertex roundedly produced, about one-fourth wider between eyes

at base than median length, produced almost one-half its length before anterior margin of eyes.

Color green, vertex with central pale median stripe and a pair of divergent pale stripes. Pronotum with three pale spots on anterior margin. Scutellum with a pale transverse band near apex.

Genitalia: Female last ventral segment roundedly produced. Male plates broad at apex and well rounded. Lateral processes concave on inner margin at apex. In lateral view appearing narrowed and concave before apex which is sharply pointed. Pygofer spines strongly rounded, notched on anterior ventral margin forming a rather long gradually tapered apical spine with the apex sharp pointed and directed anteriorly.

Holotype male from Chicago, Illinois, 1905 (Sanders), allotype female Urbana, Illinois, 1937 (Jones) and Washington, D. C., 1906 (Sanders), in DeLong collection. Male paratypes, Apple River Canyon, 1934, and Warren, Illinois, 1934 (Frison and Douglas), in Illinois Natural History Survey collection.

Empoasca biarca n. sp.

Resembling *ponderosa* in general appearance and shape of the lateral processes but with a twice curved pygofer spine and without the caudal spine on oedeagus. Length, 3.5–4 mm.

Vertex weakly produced and well rounded, a little more than half as long at middle as basal width between eyes, produced about one-third its length before anterior margin of eyes.

Color: Dull green to golden yellow without definite markings.

Genitalia: Female last ventral segment with posterior margin roundedly produced. Male plates with bluntly pointed apices. Lateral process straight as in *coccinea*. Pygofer spines long, gradually tapered, twice curved on anterior margin, apex slender, curved anteriorly.

Male holotype, San Francisco Co., California, July 25, 1912 (Ball), Allotype female, Colfax, California, June 23, 1908 (Ball) and paratypes from Colfax, California and Chilcoat, California, in Ball collection. Paratype male and female Colfax, California, in DeLong collection.

Empoasca perlonga n. sp.

Resembling *coccinea* in general appearance and shape of lateral processes but with a very long, slender characteristic spine. Length, 3 mm.

Vertex weakly produced, broadly, bluntly angled. A little wider between eyes at base than median length, produced about one-third its length before anterior margin of the eyes.

Color: Dull sordid green washed with yellow and without definite markings.

Genitalia: Female last ventral segment with posterior margin roundedly produced. Male plates rather narrow with rounded apices. Lateral processes straight as in *coccinea*. Pygofer spines very long, broad at base, abruptly narrowed and produced as a long, slender, ventrally directed spine.

Holotype male and allotype female, Cantwell Cliffs, Ohio, June 24, 1922 (DeLong) and paratype male and female same place and date, in DeLong collection. Paratype males, Neotoma, Hocking Co. (Thomas) in Osborn collection.

Empoasca caverna n. sp.

Resembling *fabae* in general appearance but with lateral processes concave on outer margin at apex and with spine broader at base and more abruptly narrowed. Length, 3.5 mm.

Vertex bluntly produced, about one-third wider between eyes than median length, produced one-half its length before anterior margin of eyes.

Color: Green washed with yellow, vertex with a median pale longitudinal stripe, a pair of pale spots at apex and a pair at base. Pronotum with three pale spots on anterior margin. Elytra with pale fuscous spot at middle.

Genitalia: Male plates broadened at middle, concavely narrowed on apical half to rather broad rounded apices. Lateral processes strongly, abruptly, concavely narrowed on outer margin forming slender pointed apices which are sometimes overlapped. Pygofer spine broad at base, abruptly narrowed to form apical slender spine which is directed ventrally and as long as basal portion.

Holotype male, Warren, Illinois, August 22, 1936 (DeLong and Ross), in the Illinois Natural History Survey collection.

Empoasca decurvata n. sp.

Resembling *curvata* both in general appearance and internal male genitalia but with characteristic lateral processes and longer pygofer spine. Length, 3.5 mm.

Vertex produced and angled, one-third longer on middle than width between the eyes, produced about one-half its length before the anterior margin of the eyes.

Color: Green, vertex with a central stripe, two apical oblique and two basal oblique white dashes. Pronotum with three anterior white spots. Scutellum with central third occupied by a broad white longitudinal stripe.

Genitalia: Female last ventral segment strongly, roundedly produced. Male plates rather broadly rounded at apex. Lateral processes in ventral view rather strongly curved inwardly with the apices curved abruptly outwardly and extending laterally. Spines of pygofer long, gradually narrowed, apical half produced as a narrow spine extending ventrally and curved slightly anteriorly.

Holotype male and allotype female, Clarksville, Tennessee, July 14, 1915, and paratypes from Clarksville and Colliersville, Tennessee, are in the DeLong collection. Male and female paratypes, Douglas Co., Kansas, in the Snow Collection, University of Kansas.

Empoasca pergrada n. sp.

Resembling *panda* both externally and internally. The lateral processes more broadened at apex and the pygofer spine more tapered to apical portion. Length, 3 mm.

Vertex strongly produced and bluntly angled, two-thirds as long as basal width, produced one-half its length before anterior margin of eyes.

Color: Pale yellowish-green, usually with the three longitudinal pale areas on the vertex, the three pale spots on anterior margin of pronotum and a transverse pale spot on scutellum.

Genitalia: Female last ventral segment roundedly produced. Male plates well rounded at apex. Lateral processes narrowed at apex, apices bent obliquely inwardly, usually overlapping. Pygofer spines broad at base, abruptly narrowed so that apical half forms a slender spine which is directed obliquely ventro-anteriorly.

Holotype male, Decatur, Georgia (Auten), allotype female, Taylor's Falls, Minnesota, August 16, 1916 (DeLong) and paratype males and females, Taylor's Falls, Minnesota, Biloxi, Mississippi (Grimes), in DeLong collection. Male paratypes, Alton and White Pine Forest Park, Illinois (Ross, Frison, DeLong), in Illinois Natural History Survey collection.

Empoasca luda n. sp.

Resembling *smaragdula* in size and internal male genitalia, but with a broad, short spine. Length, 4.2 mm.

Vertex broadly rounded, more than twice as broad as median length, produced about one-third its length before anterior margin of eyes.

Color: Dull green washed with yellow and brown. Vertex, pronotum and scutellum predominantly brownish with yellowish-green paler areas. Elytra dull green, veins brown.

Genitalia: Male plates with well rounded apices. Lateral processes straight, pointed at apices. Pygofer spines broad, deeply rounded, notched on anterior apical half forming a curved spine on ventral caudal margin which is directed ventrally with the apex pointing anteriorly.

Holotype male, Wooster, Ohio (Houser) taken in galleries of *Crabro davidsoni* and paratype male Urbana, Illinois, 1917, in DeLong collection.

Empoasca excava n. sp.

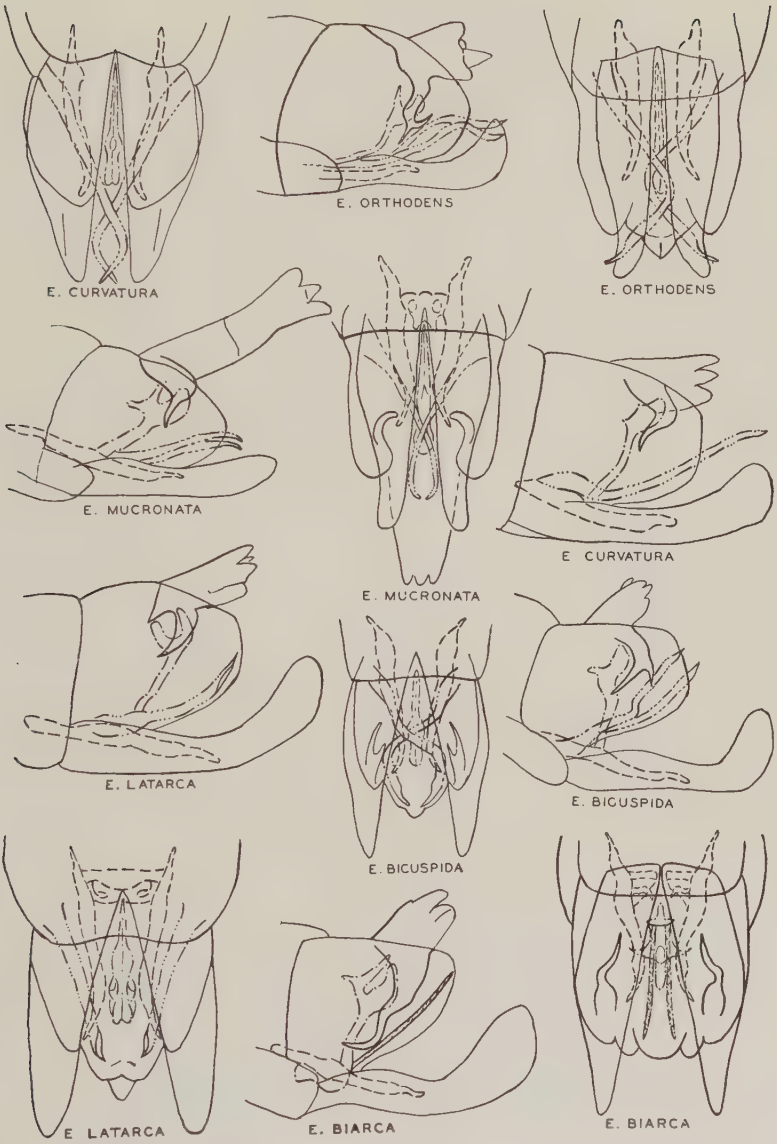
Resembling *digita* externally but with lateral processes roundedly, abruptly narrowed at apex, concave ventrally and on outer margin with apices turned outwardly. Length, 4 mm.

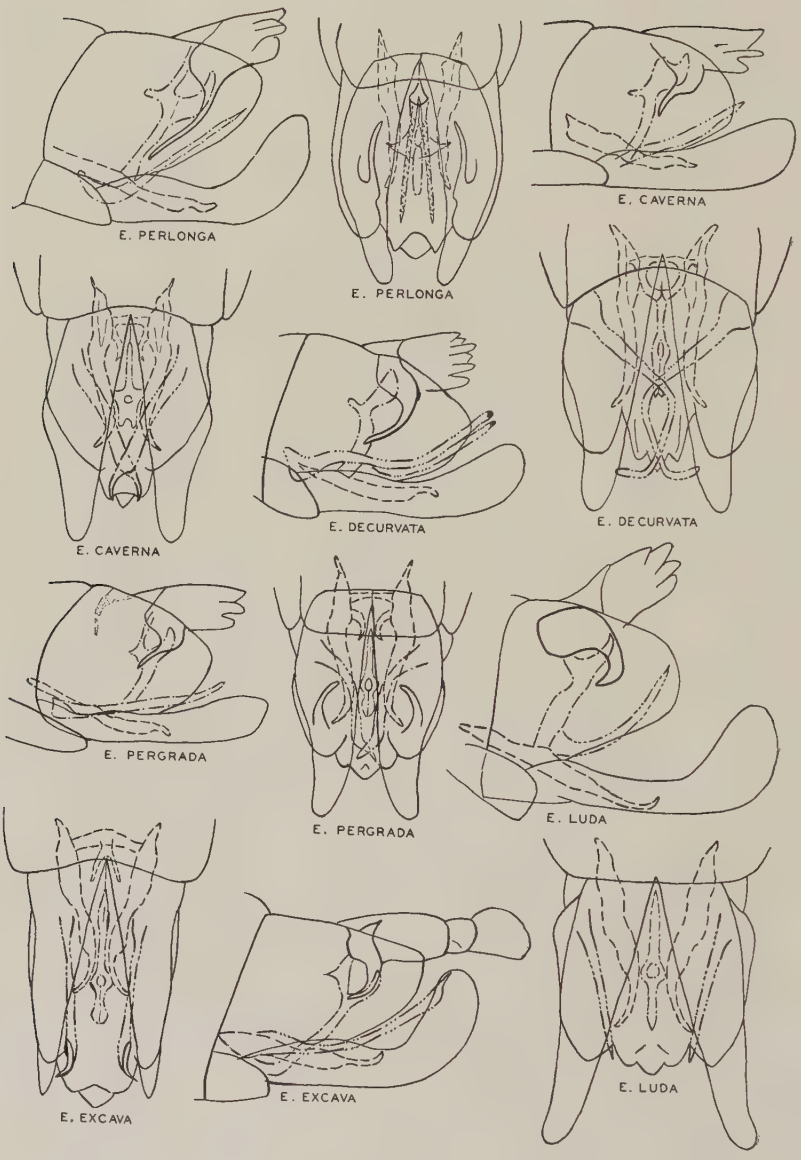
Vertex broadly rounded, slightly produced, more than twice wider than median length and produced about one-third its length before anterior margin of eyes.

Color: Dull green washed with golden yellow, pronotum often with the three pale areas on anterior margin, the median one often forming a pale stripe, and scutellum with longitudinal pale stripe.

Genitalia: Female last ventral segment roundedly produced. Male plates long, gradually tapered to bluntly pointed apices. Lateral processes narrowed near apex with tips slender and pointed outwardly, process concave ventrally and on outer margins at apex. Pygofer spine rather short, abruptly narrow at about half its length on anterior margin with apex curved anteriorly.

Holotype male from Clarksville, Tennessee, July, 1915 (DeLong), allotype female LaPrelle, Texas, November (Knull) and male and female paratypes Oklahoma (Standish-Kaiser), Texas (Knull) and Tennessee (DeLong), in the DeLong collection. Male and female paratypes, Vienna, Ursa and Havana, Illinois (Ross, Mohr, Burks, DeLong), in Illinois Natural History Survey collection.


E. CURVATURA
E. ORTHODENS
E. ORTHODENS
E. MUCRONATA
E. MUCRONATA
E CURVATURA
E. LATARCA
E. BICUSPIDA
E. BICUSPIDA
E LATARCA
E. BIARCA
E. BIARCA


E. PERLONGA
E. PERLONGA
E. CAVERNA
E. CAVERNA
E. DECURVATA
E. DECURVATA
E. PERGRADA
E. PERGRADA
E. LUDA
E. EXCAVA
E. EXCAVA
E. LUDA

FIVE NEW SPECIES OF COLEOPTERA
(Corynetidae, Elateridae and Buprestidae)

JOSEF N. KNULL
The Ohio State University, Columbus, Ohio

Pelonides similis n. sp.

Form and size of *P. humeralis* Horn; mouth parts, except last joints of palpi, thorax and part of elytra orange, apical third of elytra with a transverse piceous band which is produced in a narrow stripe along suture to basal fourth of elytra, scutellum, head, antennae, last joints of both palpi, ventral surface with exception of prothorax and legs, piceous.

Head convex; surface coarsely punctured, punctures separated by less than their own diameters; pubescence long; antennae ten-jointed, last three joints longer than all of others united, eighth and ninth joints triangular, slightly longer than wide, last joint nearly as long as eighth and ninth joints taken together; eyes finely granulate, emarginate in front.

Pronotum as long as wide, wider in front than at base; sides parallel in front, broadly rounded at base; disk convex; surface coarsely punctured, each puncture bearing a long silken hair. Scutellum rectangular, punctures small, sparse.

Elytra wider than pronotum, wider in rear than at base; sides divergent to broadly rounded apices; disk convex; surface covered with large granules, pubescence long.

First tarsal joint shorter than second.

Length, 4.8 mm.; width, 2 mm.

Described from two specimens collected in the Davis Mountains, Texas, June 2, 1937, by D. J. and J. N. Knull. Holotype and paratype in writer's collection.

Variations: The paratype has the elytra piceous with the exception of a transverse orange band at base which extends over umbone and down suture.

The species resembles *P. humeralis* Horn, but can be separated by the punctures of head and pronotum being much coarser. The species also lacks the dark central area on the pronotum of the type[1] and other specimens of *P. humeralis* Horn which I have seen.

Ampedus (Elater) obscurus n. sp.

Female.—Elongate, brunneus, mouth parts, antennae, legs and last two ventral segments of abdomen lighter, densely clothed with short brunneus pubescence.

[1]The writer is indebted to Mr. E. T. Cresson, Jr., of the Academy of Natural Science, for the privilege of studying the Horn types and also to Prof. H. C. Fall for examining the specimen.

Head coarsely, closely punctured; antennae not reaching hind angles of pronotum, scape stout, second joint longer than wide, third joint longer than second, fourth joint longer than third, joints four to ten inclusive of equal length, serrate, last joint longer than tenth.

Pronotum longer than wide, narrower in front than in rear, hind angles produced; sides broadly rounded in front, nearly parallel in basal half; disk convex, hind angles bicarinate; surface coarsely punctured in front and at sides, rest of area with punctures not well defined. Scutellum nearly round, finely punctured.

Elytra slightly narrower than pronotum; sides nearly parallel in front, broadly rounded back of middle; disk convex; surface with striae finely closely punctured, punctures separated by distances less than their own diameters, intervals finely punctured.

Beneath with abdominal segments densely finely punctured; prosternum convex, prosternal lobe broadly rounded.

Length, 7.1 mm.; width, 2 mm.

Described from one female specimen labeled Dixie National Forest, Nev., June 30, 1937, D. J. and J. N. Knull collectors, in collection of author.

This species[2] would probably stand next to *A. rhodopus* Lec., from which it can be separated by the lack of the strong punctures of the pronotum.

Anchastus uniquus n. sp.

Female.—Robust, depressed, shining, castaneous, clothed with light brown pubescence.

Head convex; surface coarsely punctured; eyes very small, finely granulate; antennae reaching to hind angles of pronotum when laid along side margins, scape stout, second joint longer than broad, third joint longer than second, fourth joint not as long as second and third united, joints four to ten inclusive of about equal length, serrate, eleventh joint longer than tenth.

Pronotum wider than long, wider at base than in front, hind angles strongly produced; sides broadly rounded in front, nearly parallel at base; disk convex, hind angles bicarinate, carinae of about equal length; surface densely coarsely punctured in front and along sides, punctures separated by less than their own diameters, other punctures light and separated by about their own diameters. Scutellum oval, coarsely punctured.

Elytra at base not as wide as base of pronotum, wider than pronotum back of middle; sides nearly parallel at base, broadly rounded posteriorly; disk convex; surface finely striate, punctures indistinct, intervals irregularly punctured, scabrous.

Beneath coarsely punctured in front, abdomen finely punctured, last segment very densely punctured; hind coxal plates strongly dilated internally; third tarsal segment bearing a large lobe beneath.

Length, 6 mm.; width, 2.2 mm.

Holotype female labeled Brownsville, Tex., August 8, 1937, D. J. and J. N. Knull, collectors, in collection of the author.

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[2]The writer is indebted to Mr. W. J. Brown for the examination of material.

According to Van Dyke's key[3] this species would run to *A. sericans* Cand. However, it can be distinguished by its smaller size, and shorter fourth antennal segment.

Agrilus shoemakeri n. sp.

Male.—Robust, dull bronze above and below, pubescence of elytra inconspicuous. Head strongly depressed in middle, coarsely punctured, becoming rugose on vertex; antennae short, not reaching middle of pronotum when laid along side margins, serrate from the fifth joint.

Pronotum as long as wide, apex and base of about equal width, widest in front of middle; sides broadly rounded in front, constricted at base, when viewed from the side, marginal and submarginal carinae separated in front but joined back to middle; anterior margin strongly lobed; basal margin trisinuate; disk convex, a strong median depression extending from back of apex to base, lateral depressions well marked, prehumeral carinae distinct; surface transversely rugose, punctures fine between rugae. Scutellum granulate, carina absent.

Elytra wider than base of pronotum; sides rounded in front, constricted in middle, broadly rounded posteriorly to rounded apices, margin serrate back of middle; disk convex, sutural margin elevated posteriorly, basal depressions well marked; surface imbricate.

Abdomen beneath transversely imbricate; first and part of second ventral slightly channeled; suture between first two ventrals not indicated at sides. Prosternal lobe broadly rounded, a line of long pubescence extending from prosternum to second abdominal segment. Hind coxae with posterior margin sinuate, outer posterior angle prolonged. Anterior and middle tibiae mucronate on inner margin at apex, posterior tarsi not longer than tibiae. Tarsal claws similar on all feet, cleft, the inner tooth slightly broader than the outer one.

Length, 5.8 mm.; width, 1.5 mm.

Described from one male specimen collected at Nogales, Santa Cruz Co., Ariz., August 31, 1906, by F. W. Numenmacher, in the collection of the late Chas. Schaeffer.

I take pleasure in naming this species after Mr. Ernest Shoemaker, to whom I am indebted for the specimen. Holotype in collection of writer.

According to Fisher's key[4] this species would run to *A. imbellis* Crotch. It can be separated by the median depression of pronotum. The genitalia resemble those of *A. illectus* Fall as figured by Fisher.

Agrilus neoprosopidus n. sp.

Male.—Size and form of *A. egenus* Gory, bronze, front bright green, each elytron with three indistinct pubescent spots, one in basal depression, one back of middle, and one on apical fourth along suture.

Head convex, no median depression; front granulate, vertex strongly punctured; antennae not reaching to middle of pronotum when laid along side margin, serrate from the fifth joint.

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[3]E. C. Van Dyke, Proc. Calif. Acad. Sci. 22: 291–465, 1932.

[4]W. S. Fisher, U. S. Nat. Mus. Bul. 145, pp. 1–349, 1928.

Pronotum wider than long, widest in middle; wider at base than at apex; sides broadly rounded in front, constricted at base, when viewed from the side, marginal and submarginal carinae separated for their entire length; disk somewhat flattened, a slight impression in front of scutellum, lateral depressions well marked, prehumeral carinae prominent; surface obliquely strigate, punctures between strigae fine. Scutellum granulate, transversely carinate.

Elytra wider than base of pronotum; sides broadly rounded in front, constricted in middle, apices rounded, serrulate; disk convex, sutural margin elevated posteriorly; basal depressions well marked, surface imbricate, pubescence short.

Abdomen beneath lightly punctured, pubescence short, first two ventrals not modified. Prosternal lobe truncate, slightly emarginate; prosternal process with sides parallel to behind coxal cavities. Tibiae of first two pairs of legs mucronate on inner margin at apex. Tarsal claws similar on all feet, cleft, the inner tooth much broader than the outer one and not turned inward.

Length, 4.5 mm.; width, 1.1 mm.

Described from one male specimen collected at Brownsville, Texas, May 12, 1935, by the author. Holotype in writer's collection.

According to Fisher's key[4] this species would run to *A. prosopidus* Fisher. It can be separated by the male genitalia which resemble those of *A. paramasculinus* Knull as figured by Fisher. The pronotum is less convex.

Experimental Design and Statistical Analysis

The intimate relationship between the design or logical structure of an experiment and its statistical analysis is a new and rapidly progressing study. It becomes increasingly clear that the biologist should make himself thoroughly familiar with the methods of statistics *before* rather than after his experiments are performed. Professor Snedecor has taken advantage of every opportunity to discuss these "questions of design" in connection with the mathematical procedures discussed in his new manual.

The book has many other features which appeal to the biologist. The exposition is developmental and each statistical technique is illustrated with several sets of data drawn from a wide variety of experiments. Each chapter also includes many unworked exercises, together with answers. This makes it especially valuable as a manual for self-instruction or as a text. Mathematical questions are largely omitted. An arithmetical "proof" is preferred to an algebraic one. Special attention is given to methods of machine calculation.

Emphasis is placed upon the precise formulation of a null hypothesis upon which the statistical argument is rested. This tends to give the reader a clearer grasp of the underlying similarities of the various statistical operations which he performs. The all-important distinction between population parameters and sample statistics is insisted upon throughout. All of the methods are applicable to small scale experiments, being based upon the distributions of chi-square, t, and F, using the concept of degrees of freedom. Large sample approximations are introduced only as special cases.—*C. W. Cotterman.*

Statistical Methods, by George W. Snedecor. xiii+341 pp. Ames, Iowa, the Collegiate Press, Inc. 1937. $3.75.